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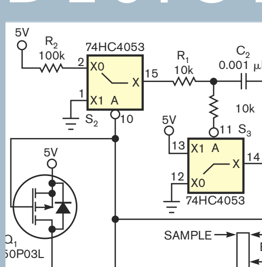
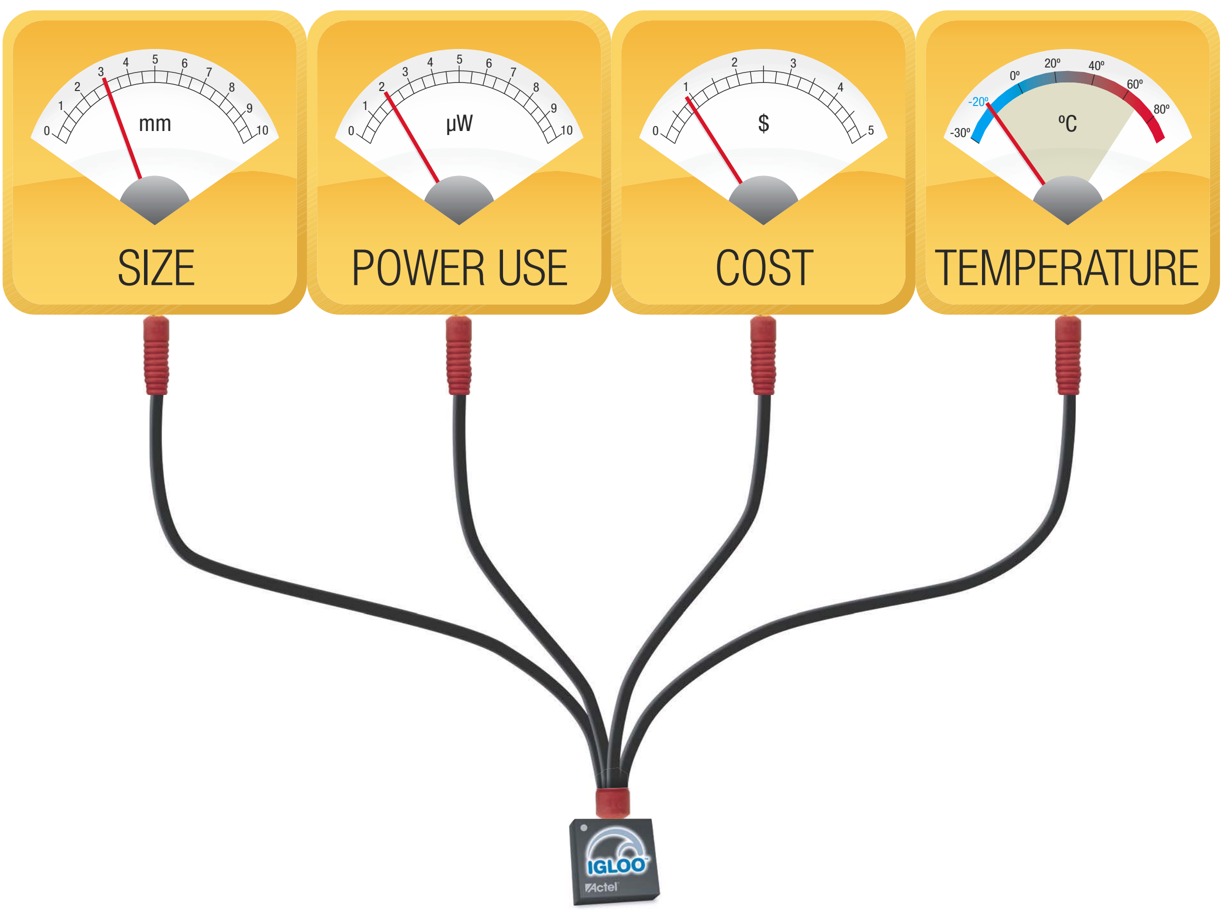


Zero lead time for production quantities



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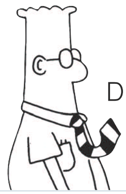

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DEPARTMENTS & COLUMNS

PRODUCT ROUNDUP

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Getting clock-domain crossings right: some notes from the real world
CDC (clock-domain-crossing) errors are potential chip-killers, are easy to create—even automatically courtesy of well-meaning design tools—and are marvelously hard to detect.
→www.edn.com/081127toc1

Intel versus AMD: the final-chapter entry?
AMD, it seems to me, desperately needs a big break (either in the courts or in the marketplace) to regain its stride. But Intel doesn't seem inclined to give it one.
→www.edn.com/081127toc2

The most important product feature
The most important product feature is the one that gets the customer to plunk money on the counter—whether or not that feature involves engineering.
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SEE NAKED ICs
The IC Insider, an exclusive EDN.com series contributed by Chipworks, strips down modern ICs with scanning-electron-microscope imagery, circuit schematics, and an in-depth discussion. Check out the previous installments and the new entry, which debuts Dec 1.
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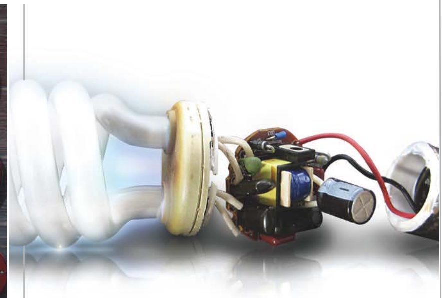

READERS' CHOICE

A selection of recent articles receiving high traffic on www.edn.com.

This was not the right application for a compact fluorescent light
There's been a backlash against CFLs (compact fluorescent lights)—especially since the federal law was passed last year that mandates the replacement of all incandescent bulbs by 2012—by users complaining that the lights have a shorter life span than advertised. My personal experience is that CFL lifetime is influenced by its application.
→www.edn.com/081127toc7

Transimpedance-amplifier application: the pulse oximeter
→www.edn.com/article/CA6607193

Studying the second-generation Apple iPod Touch
→www.edn.com/article/CA6600223

TI cuts wireless investments, plans to sell cellular-baseband operation
→www.edn.com/article/CA6607233

Cadence: the picture gets darker
→www.edn.com/081127toc8

EDN INNOVATION
NOMINATION DEADLINE EXTENDED
We've extended the deadline for nominations in EDN's 19th annual Innovation Awards, which will take place in March 2009. Hurry, the final deadline is Dec 5.
→www.edn.com/innovation

BY RICK NELSON, EDITOR-IN-CHIEF

From lithography to test

This year, I commented on the importance of taking test into account during the design phase (**Reference 1**). Examples I cited included Asset InterTech's focus on providing open tools for embedded instrumentation in design-validation, test, and debugging applications. The company reiterated that focus last month at the ITC (International Test Conference) in Santa Clara, CA, when it announced that it has joined the Synopsys in-Sync program to gain access to Synopsys' Galaxy test tools. For its part, Cadence Design Systems announced at ITC that Moai Electronics has made joint use of the Cadence Encounter RTL-(register-transfer-level) Compiler design tool and Encounter Test design-for-test tool to tape out a flash-memory controller, reducing RTL-to-ATPG (automatic-test-pattern-generation) turnaround time from weeks to days.

Test—one of the last steps to take place before product shipment—isn't the only aspect of semiconductor production that designers should address for optimum results, however. Designers must also take into account manufacturing issues that appear as early as the lithography stage. That fact became clear at a research-review meeting held in October at ASML in Veldhoven, the Netherlands. At the meeting, presenters discussed the importance of computational lithography in, for example, producing 22-nm features using 193-nm light waves—that is, "creating thin lines with a broad brush," said Neal Callan, ASML's vice president for marketing and product development.

The need for manufacturing-aware design tools is not new, and EDA companies have been addressing the issue, as I noted in a blog post more than two years ago (**Reference 2**). The need for the OPC (optical-proximity-correction) DFM (design-for-manufacture) technique kicked in when processes approached 130 nm, said Callan at the meeting. And it's becoming increasingly important as lithography companies turn to double-patterning as an interim approach that will serve until EUV (extreme-ultraviolet) lithography becomes available, which is expected to be in 2010, according to ASML fellow Jo Finders.

Finders described the double-patterning flow, which requires dividing a layout into two patterns for the production of two masks, with patterns recombining through double exposure of the target die. Successful application of the technique, he said, depends on an overlay-friendly layout that in turn depends on effective DFM tools.

ASML is addressing double-patterning with its recently introduced Twinscan NXT platform, which the company says will enable manufacturers' need to shrink their smallest chip features by as much as 42%. ASML addresses the DFM aspect through its Brion subsidiary, which it acquired in 2007. Suggesting how complex the technology is, Callan noted the need to optimize not only the mask but also the light source to produce the best images. The forte of Brion and competing DFM organizations is mask optimization through OPC and other techniques. To address double-patterning in particular, Brion's approaches, Callan said, provide gate-aware splitting of images and ensure density balance between two corresponding patterns.

Callan noted that computational lithography depends on accurate modeling and, not surprisingly, that Brion's intimate knowledge of ASML scanners enables better image prediction. However, ASML doesn't intend to keep all its scanner knowledge to itself. Through Brion, Callan said, ASML will proliferate ASML scanner models throughout the DFM value chain through the VSP (Virtual Scanner Pack), which will be available to EDA companies, including Cadence, Magma Design Automation, Mentor Graphics, and Synopsys. Customers who use design or computational-lithography tools from any company can access ASML scanner models through the VSP, which should benefit chip-design software companies as well as chip manufacturers. **EDN**

REFERENCES

1. Nelson, Rick, "The design-and-test merger," *EDN*, June 26, 2008, pg 12, www.edn.com/article/CA6571005.
2. Nelson, Rick, "DFM's hot, but what is it?" *Test & Measurement World*, June 6, 2006, www.tmworld.com/blog/640000064/post/880003488.html.

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Reed Electronics Group

Test system spans digital, RF domains

Agilent Technologies has announced the DigRF (digital-radio-frequency) V4 test system. The product provides comprehensive stimulus and analysis for developers of RFICs (radio-frequency integrated circuits) and baseband ICs, as well as integrators of wireless handsets. DigRF V4, a standard of the MIPI (Mobile Industry Processor Interface) Alliance (www.mipi.org), defines a high-speed digital-serial bus between mobile baseband and RF chips. DigRF V4 technology is a key enabler for LTE (long-term evolution) and WiMax (worldwide-interoperability-for-microwave-access) wireless communication.

DigRF V4 necessitates cross-domain testing, which provides new insights about signals from the level of individual digital bits through IQ (in-phase/quadrature)-modulated RF carriers. The test system allows engineers to work in the digital or the RF domain and the physical- or the protocol-layer abstraction level of their choice to quickly characterize RFICs and rapidly solve cross-domain-integration problems.

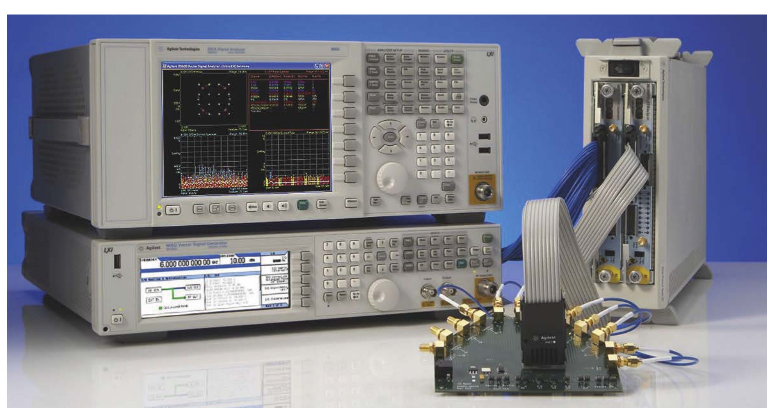
The test system integrates stimulus- and protocol-analysis tools into the manufacturer's portfolio of digital, RF, and wireless-communication test instruments. The RDX (radio-digital-cross-domain) tester comprises the N5343A analyzer and the N5344A exerciser, which mount within the company's small, modular N2X mainframes and accommodate future MIMO (multiple-input/multiple-output) designs.

The N5345A and B5346A active-probing subsystems with capacitance loading of less than 0.15 pF and high sensitivity provide system insight with minimum-disturbance testing at DigRF V4's 1-Gbps data rates. The N5345A Midbus Probe with Soft Touch technology enables fast probing on prototype boards, and the B5346A flying-lead probes enable effortless monitoring of DigRF V4 links in space-constrained designs.

The system architecture also protects your investment by supporting both the DigRF V4 and V3 specifications. The test-software environment includes protocol generation and analysis and operates with the manufacturer's Signal Studio software and 89600 vector-signal-analysis software. The design approach saves you time by using familiar vector-signal generation and analysis software, which supports the DigRF exerciser and analyzer modules, as well as other signal analyzers and signal sources.

US prices for the N5343A analyzer and N5344A exerciser modules start at $15,000 per module, including software. US prices for the N5345A and B5346A active probes start at $22,000.**—by Dan Strassberg**

▷**Agilent Technologies**, www.agilent.com/find/digrf.



The principal components of the DigRF V4 test system are the RDX exerciser and analyzer modules (in the small mainframe at right) and midbus and flying-lead active-probe subsystems (not shown). Each of the probe subsystems includes an electronics module, which is somewhat smaller than the vector-signal generator (lower left). Above this generator is a vector-signal analyzer.

FEEDBACK LOOP

"Too many forget that what may be the cat's meow for the influential privileged (of which there are, admittedly, many) can greatly disadvantage the rest. We need to keep perspective."

—Reader Donald H Locker, in *EDN*'s Feedback Loop, at www.edn.com/article/CA6602449. Add your comments.

PSoC supports CyFi low-power RF

Developers can now use Cypress Semiconductor's PSoC (programmable system-on-chip) devices with the company's new, 2.4-GHz CyFi low-power RF product, which combines a PSoC processor running the CyFi star-network-protocol stack and the CYRF7936 CyFi transceiver. The approach employs DSSS (direct-sequence-spread-spectrum) modulation and the ability to move across 80 channels in the 2.4-GHz band to provide interference immunity. The CYRF7936 CyFi transceiver is available in a 40-pin QFN package. Evaluation and development kits that support the CyFi transceiver, including the CY3271 PSoC FirstTouch starter kit, the CY3271-exp1 environmental-sensing kit, the CY3271-RFboard RF-expansion kit with CyFi technology, and the CY3210-CyFi development kit, are also available.

PSoC processors integrate a microcontroller with run-time-reconfigurable analog and digital circuits that can supply as many as 100 peripheral functions in one device. The devices include as much as 32 kbytes of flash memory, 2 kbytes of SRAM, an 8×8-bit multiplier with a 32-bit accumulator, power- and sleep-monitoring circuits, and hardware-I^{2}C communications. The development tools enable designers to select configurable library elements for analog functions, such as amplifiers, ADCs, DACs, filters, and comparators, and digital functions, such as timers, counters, PWMs (pulse-width modulators), SPIs (serial-peripheral interfaces), and UARTs. The analog features include rail-to-rail inputs, programmable-gain amplifiers, and 14-bit ADCs with low noise, input leakage, and voltage offset.

> The environmental-sensing kit includes wireless pressure, humidity, temperature, and ambient-light sensors.

CyFi combines a PSoC processor running the CyFi star-network-protocol stack and the CYRF7936 CyFi transceiver.

The CyFi star-network-protocol stack is available as preconfigured firmware modules that require 8 kbytes of flash for a hub device and 5 kbytes of flash for a node device. Application code accesses the modules through an API (application-programming-interface)-based protocol stack that can handle as many as 250 nodes of asynchronous, bidirectional communications. The modules transparently provide active link and power management.

CyFi uses DSSS modulation to encode data so that, when the receiver encounters interference, it can recover a signal. A communication link can select a clear channel from the 80 narrow, 1-MHz channels that the transceiver supports. The implementation can dynamically increase power amplification to overcome interference. The implementation can also support a 1-Mbps, non-DSSS communication link in noise-free environments, and it can step down to 250- or 125-kbps DSSS when necessary to maintain the link. The system has a sleep current of 0.8 μA. The transceiver supports as much as 4 dBm of output power, and the receiver supports as much as −97 dBm of receiver sensitivity.

The CY3271 PSoC First-Touch USB thumb-drive starter kit with CyFi low-power RF includes the PSoC IDE (integrated-development-environment) software, a sense-and-control dashboard for data collection, a PC dongle with RF, a multifunction board, an RF-expansion board with power amplifiers for long-range-wireless applications, and two battery boards. The kit supports evaluating the touch-, temperature-, lighting-, and proximity-sensing capabilities of the PSoC device. The CY3271-exp1 environmental-sensing kit includes wireless pressure, humidity, temperature, and ambient-light sensors. The CY3271-RFboard RF-expansion kit, an add-on to the CY3271, provides two additional RF-expansion and AAA-battery boards. The CyFi low-power, general-purpose RF-development kit lets you prototype and debug with PSoC devices and CyFi transceivers. The kit includes two development boards, two PSoC modules, and three CyFi modules to build wireless-system applications.

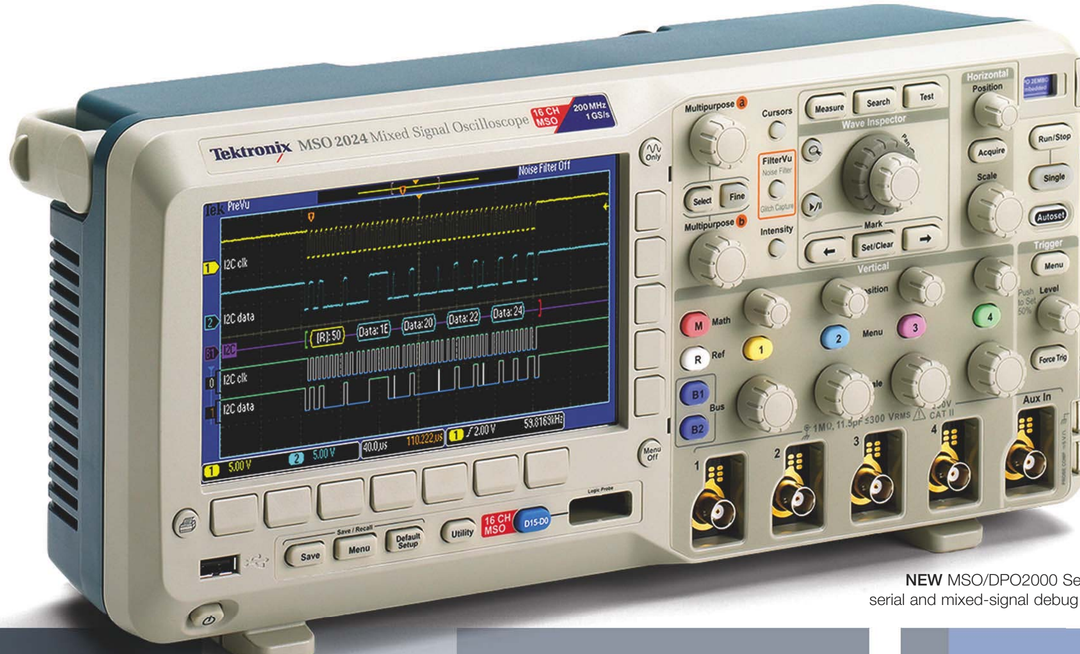
—by Robert Cravotta

▷**Cypress Semiconductor**, www.cypress.com.

DILBERT By Scott Adams

Overachiever.

NEW mixed-signal scope series with advanced features starting at $2580...



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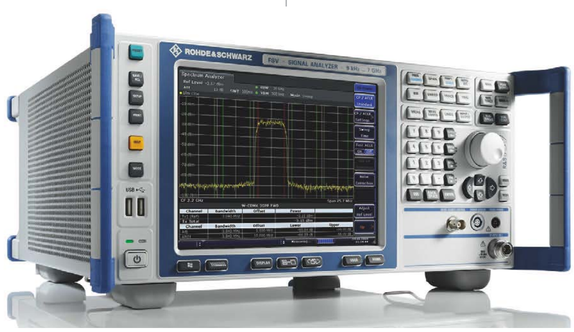
30-GHz signal analyzer offers 40-GHz bandwidth

As part of a series of instrumentation announcements in both signal generation and analysis, Rohde & Schwarz has introduced the FSV midrange signal and spectrum analyzer. The device has an analysis bandwidth of 40 MHz, enabling it to cover wireless standards from 3GPP (Third Generation Partnership Project) LTE (long-term evolution) to WLAN (wireless-local-area-network) 802.11n. Other key specification points include a 200M-sample IQ (in-phase/quadrature) record memory, a speed of 500 sweeps/sec manual or 1000 sweeps/sec automatic, and dual-mode operation through either conventional front-panel controls or the touchscreen.



The analyzer's total measurement uncertainty is 0.3 dB to 3.6 GHz and 0.4 dB to 7 GHz. As with other R&S analyzers, you can add a compatible power sensor. The instrument then becomes an accurate power meter, providing a complete set of functions, such as the measurement of channel power and adjacent-channel power in addition to spectral measurements, such as spectrum-emission masks; it offers a choice of filters and detectors. Options provide for analysis of GSM (global system for mobile) communication/EDGE (enhanced-data-GSM environment), GPP (general packetized protocol) WCDMA (wide-code-division multiple access), 3GPP LTE, WiMax (worldwide interoperability for microwave access), and WLAN. The FSV comes in two models: one with a frequency range of 9 kHz to 3.6 GHz and the other with a range of 9 kHz to 7 GHz.

—by Graham Prophet

▷**Rohde & Schwarz**, www.rohde-schwarz.com.

EDN**BLOG**

POWERSOURCE

Hand grenade or coffee thermos: two very different models of a laptop battery

Take a look at these two quotes, both regarding the amount of energy stored in a laptop battery pack. The first is from a *New York Times* article about solar-thermal-energy generation:

"The idea is to capture the sun's heat. Heat, unlike electric current, is something that the industry knows how to store cost-effectively. For example, a coffee thermos and a laptop computer's battery store about the same amount of energy, said John S O'Donnell, executive vice president of a company in the solar-thermal business, Ausra. The thermos costs about $5, and the laptop battery costs $150, he said, and 'that's why solar thermal is going to be the dominant form.'"

The second quote is from an *IEEE Spectrum* article on Christina Lampe-Onnerud, the president of lithium-ion-battery vendor Boston-Power: "She ruffled a few feathers … by pointing out in a talk that the energy density of lithium-ion batteries used for laptop computers, at 40 Whr/kg, was already getting uncomfortably close to that of your basic hand grenade. That density, the amount of energy stored in a certain mass, had been going up like a rocket as manufacturers competed fiercely for a growing market."

So, here we have two ways of looking at energy storage in a battery pack: One model is of a warm and fuzzy coffee thermos, while the other is of a nasty, violent hand grenade. How can both be accurate models of a laptop battery?

The two systems are using energy to do two very different things. The Ausra executive is pretty dismissive about our knowledge of how to store electrical energy, but it's also much easier to store energy at a relatively low temperature. On the other hand, it's hard to get any work out of low-temperature energy. Plus, energy stored as heat can only be made to do work through a heat engine (you need a cold sink too), and you're limited to the Carnot efficiency. A battery, on the other hand, stores energy chemically and isn't limited by Carnot efficiency.

The hand-grenade analogy makes the point that this is an amount of energy that can be confined to your lap and yet can be extremely destructive—especially when it's in the sensitive environment of a lap rather than a battlefield. The difference here is the rate at which energy is released. A grenade's chemistry is such that the total amount of energy isn't huge; it can do so much damage because of the rate at which it's released. Under normal operating conditions, the laptop battery releases energy slowly. Practically speaking, a laptop battery isn't going to go "boom" like a grenade because a grenade is designed to release its energy nearly instantaneously. So, that analogy is a bit deceptive also.

So, two models of one common energy-storage device. We're entering a time when there is no one-size-fits-all energy storage, and we will have to tailor our energy sources—and their storage—very carefully to their application to wring out the maximum efficiency in a cost-effective way.**—by Margery Conner**

▶www.edn.com/powersource.

▶For the full post, go to www.edn.com/081127ba.

VOICES

Avnet LightSpeed's Cary Eskow: illuminating energy-efficient design

Cary Eskow is director of LightSpeed, the solid-state-lighting- and LED (light-emitting-diode)-business unit of Avnet Electronics Marketing (www.em.avnet.com/lightspeed). A 28-year Avnet veteran, he leads Avnet's national team of illumination-focused engineers, has published more than 30 articles and columns on HB-LED (high-brightness LED)-system design, and is a member of the Underwriters Laboratory-8750 LED Standards Technical Panel. Eskow recently spoke to *EDN* about designing for the HB-LED market. Excerpts of that interview follow. For the entire interview, go to www.edn.com/081127p1.

Why is the HB-LED market in the spotlight right now?

A Initially, people are looking toward HB LEDs because of energy savings. The single greatest usage of energy in any building at around 25% tends to be lighting. Because of the physics involved and the way incandescents work, typically, an HB LED has three or four more times light output for any given amount of power input.

[You can achieve] energy efficiency by using compact fluorescents or other types of devices like that, but they all have mercury. There are about 13 states that have legislation pending or in force that restricts the use of or mandates special handling of mercury-containing lamps. So, at some point, you have a convergence of legislation that mandates energy-efficient lighting and other legislation that increases awareness of hazardous materials [such as] mercury. The only real lighting source that satisfies both is HB LEDs.

What's the design challenge?

A The challenge with LEDs is, with the exception of infrared LEDs, they get hot. Based on certain things that happen with the semiconductor, that heat cannot escape in the form of infrared energy. The most significant design challenge—the one that people typically don't anticipate when they begin an HB-LED design—is pulling the heat out of the device.

HB LEDs are more energy-efficient than incandescent and fluorescent lights, but, at the system level, does that advantage fade because of power loss?

A On the system level, it is still far more advantageous to use an LED over an incandescent. An incandescent doesn't have any converter, but maybe 5 to 7% of the energy that goes into a bulb comes out as white light. In an LED-based system, yes, when you convert from the ac power to the con-

stant-current dc typical low voltage that an LED requires, there may be 10 or 15% of loss in the circuitry. However, you gain that [loss] back because so much of the input energy going into an LED is realized and radiated as useful light, not as infrared or ultraviolet or other things that you don't want.

If you compare compact fluorescents or regular fluorescents, they are pretty efficient and are very close to what an LED can provide as far as lumens, which is the way you measure light per watt. However, there are some big negatives with fluorescent tubes and compact fluorescents. One of them is lifetime. They don't last a long time. The second thing is that they are filled with mercury gas—not a lot, but it's in there, and that's why they are considered hazardous wastes.

Can you outline the Energy Star regulations and how they apply to solid-state lighting?

A [The Department of Energy] came up with a set of specifications that include quality, exactly how much light must be put out in a given area in a given situation, the efficiency, even the manufacturer's warranty. If all these requirements are met, that product can be Energy Star-certified.

It's really a quality-control system, not just a matter of energy efficiency. And it's difficult to achieve, by the way. So, when a solid-state-light product is Energy Star-certified, it's been well-designed.

Why do you think it is important for engineers to work with distributors such as Avnet on specialized system-level design assistance when it comes to HB LEDs?

A A number of companies have rapidly advanced the art of producing efficient HB LEDs. Furthermore, the ICs and other components required for a constant-current-HB-LED supply are certainly not difficult to use. What is missing, however, is knowledge of how to design an illumination system. You can liken this to FPGAs [field-programmable gate arrays] back in 1985—when their adoption was paced by the knowledge of how to apply them. That's where we are now with solid-state lighting.

The most valuable commodity related to HB LEDs isn't sourced by any supplier; it's the experience and system-level knowledge of how to best leverage HB LEDs in your specific application. This [knowledge] usually entails a proper understanding of secondary optics, comprehensive modeling of the application's thermal requirements, careful HB-LED-device selection, and experience in derating HB-LED-performance data.

Of course, data-sheet interpretation, modeling, and careful design are not new disciplines for engineers, but doing this [work] with light and LEDs can be a major task. In six or seven years, HB-LED products will be common commodities, and system-level optical/thermal knowledge will be pervasive. It just isn't yet.**—Interview conducted and edited by Suzanne Deffree**

BY BONNIE BAKER

Just use a 100Ω resistor

So there I was, a new hire for a leading-edge analog-electronics company. As it was my first job, I was wide-eyed and excited—confronting new problems left and right. One problem I ran into involved the stability of an amplifier circuit. In this application, a buffer-amplifier circuit, with a capacitive load, sang like a bird. Because I had a huge community of experts around me, I ran around and asked for advice. The words of wisdom that came down to me were, "Oh, put a 100Ω load resistor between the amplifier output and the load capacitor." When I asked why, the engineer said, "Just do it. *Trust* me; it will work."

So, I built a new circuit as suggested, and, lo and behold, the circuit still oscillated. This new circuit was still singing, but it was producing a new frequency. I returned to the engineer who gave me the first bit of great advice. His recommendation: "Change the 100Ω resistor to a 500Ω resistor," still with no explanation. It solved my problem, but, given my work load, I did not return to his suggestion for several years. Now, it has come back to haunt me. I need to know what is really going on!

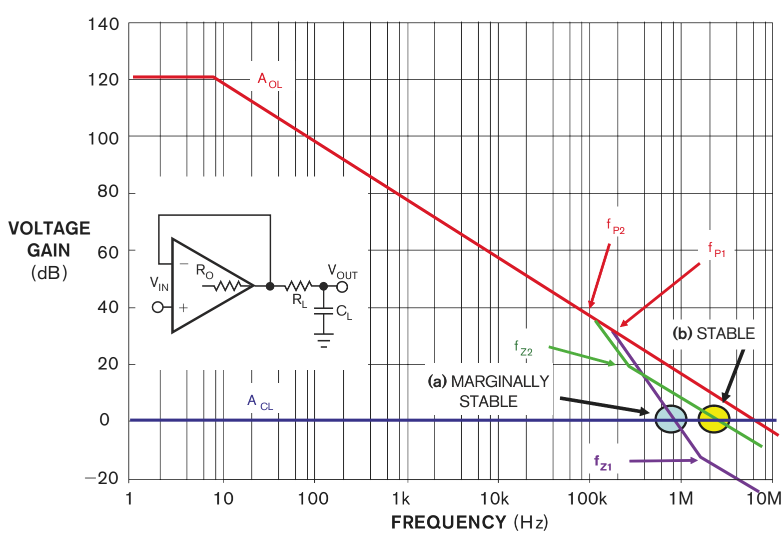


Figure 1 A buffer-amplifier circuit with a capacitive load can be marginally stable (a) or very stable (b). Keep the rate of closure between the open-loop-gain, A_{OL}, and the closed-loop-gain, A_{CL}, slope at 20 dB/decade.

What I did not understand then but understand now is that a capacitor and a resistor that hang on the output of an amplifier change the amplifier's open-loop-gain curve. The combination of the load capacitor, C_L; the load resistor, R_L; and the amplifier's open-loop resistance, R_O, introduces a pole to the open-loop-gain curve, and C_L and R_L then introduce a zero to the open-loop-gain curve (**Figure 1**). Creating this pole and zero does not disrupt the amplifier's stability as long as they cancel each other out before the open-loop-gain curve crosses the closed-loop-gain curve. If the open-loop-gain and closed-loop-gain curves cross with a 40-dB/decade closure rate, the amplifier circuit will be marginally unstable or, worse yet, will oscillate.

You can find the pole and zero locations in this circuit in the following **equations**:

$$f_P = \frac{1}{2\pi(R_O + R_L)C_L}.$$

$$f_Z = \frac{1}{2\pi R_L C_L}.$$

What have I learned from this situation? It pays to understand why an engineer's rule of thumb works. If you comprehend the general guidelines, you will be OK. If you are not on top of the explanation, however, it will come back to bite you.**EDN**

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BY JOSHUA ISRAELSOHN, CONTRIBUTING TECHNICAL EDITOR

Know your ceramic capacitor, part two

The last installment of *Analog Domain* introduced the four classifications of ceramic capacitors that the EIA (Electronics Industries Alliance) defines in its standard EIA 198-1F (**references 1** and **2**). The standard defines the attributes associated with the familiar, if cryptic, designations that identify various ceramic capacitors, including C0G, X7R, and Z5U—members of EIA classes I, II, and III, respectively. The designations correspond to the electrical and thermal behaviors that characterize ceramic capacitors' various dielectric formulations.

As I noted in that article, Class I ceramics excel with the lowest temperature coefficients of capacitance, the lowest voltage coefficients of capacitance, and the highest Q of the four EIA ceramic-dielectric types. The disadvantages of Class I ceramics include their low dielectric constants, constraining the upper extent of the capacitance range that manufacturers can provide within a given case size. For a given capacitance requirement, this constraint in turn limits an application's density and increases its component costs.

Applications not demanding Class I ceramics' parametric performance can take advantage of the greater densities and lower costs attainable with ceramic classes II and III, which feature significantly larger dielectric constants. The more space- and cost-efficient Class II ceramics, however, exhibit parametric shifts for which you must account when specifying these devices.

The most obvious shift results from the temperature coefficient of capacitance. Capacitors conforming to EIA classes II and III do not specify a temperature coefficient in such terms but rather a temperature range and a maximum capacitance shift over that range (**tables 1** and **2**, available in the Web version of this column at www.edn.com/081127ji). X7R capacitors, for example, feature an operating-temperature range of −55 to −125°C, over which the capacitance can vary ±15%.

> **Applications not demanding Class I ceramics' parametric performance can take advantage of the greater densities and lower costs attainable with classes II and III.**

Class III capacitors, the least expensive of the common types, raise concerns if the component-selection process does not properly take into account their characteristics. The operating-temperature range of Z5U, for example, extends to only 10°C, which is insufficient for most portable electronics in which Class III devices' density is particularly attractive. Also, over the narrow 75°C operating range, a Z5U device's capacitance can drop by more than half. Another popular Class III device, Y5V, provides guaranteed performance to −30°C, but, over its 115°C operating range, its capacitance can fall to one-fifth its nominal value.

Ceramic capacitors in classes II and III also present a significant and nonlinear voltage coefficient of capacitance. The capacitance of Class II devices typically falls 10% with applied voltages of 50 to 70% of the device's maximum working voltage. Class III devices lose capacitance starting at 10% of the maximum working voltage and exhibit as little as 30% of their nameplate value at 90% of their voltage range.

Designers involved with typical low-voltage CMOS applications see typical working-voltage maximums of 50 and 100V, so they needn't concern themselves with the voltage effect. However, those designing higher-voltage circuits for applications such as analog-signal processing and motion control should make note of the voltage effect on the capacitors they specify and adjust the design values to the components' behavior. **EDN**

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Joshua Israelsohn is a co-founder of JAS Technical Media, where he manages technical-communication services. You can find his contact information at www.jas-technicalmedia.com/Contact.

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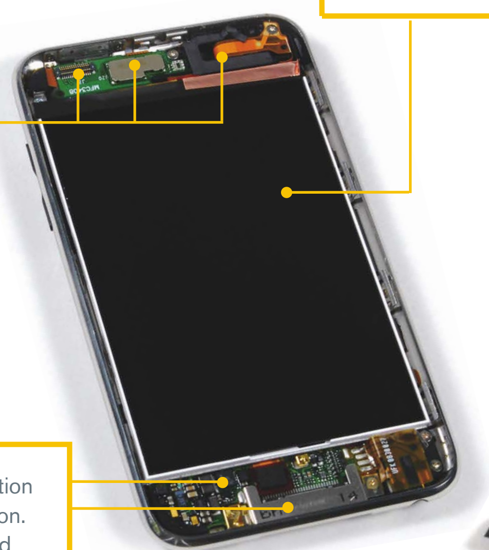
Studying the second-generation iPod Touch

A partnership with iFixit bears abundant fruit: high-resolution images of the innards of Apple's latest high-end iPod product. What sustenance, seeds, and worms does an intensive inspection reveal?

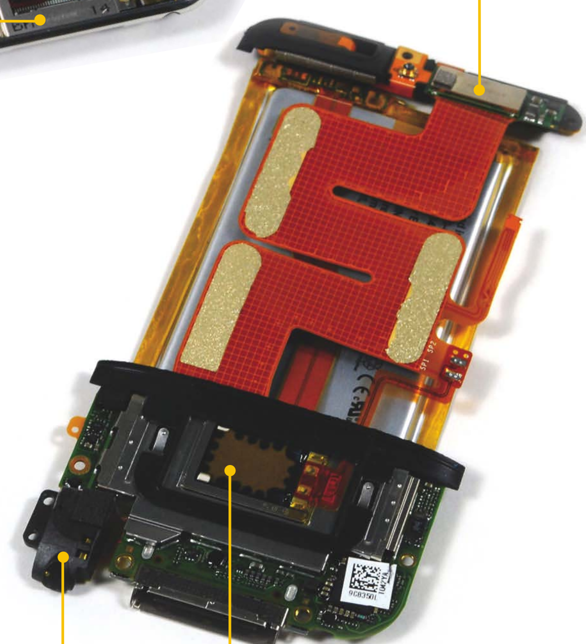
The touchscreen LCD measures 3.5 in. diagonal, with 480×320-pixel resolution and a 163-pixel/in.^{2} pitch. Underneath it is the lithium-ion polymer battery.

The connector in the upper-left corner mates with the unit's ambient-light sensor, which controls the LCD backlight. In the upper-right corner is a portion of the 2.4-GHz antenna, also visible in the other photo. Between them and underneath an RF shield is the combination of the touchscreen controller and the backlight-control circuitry.

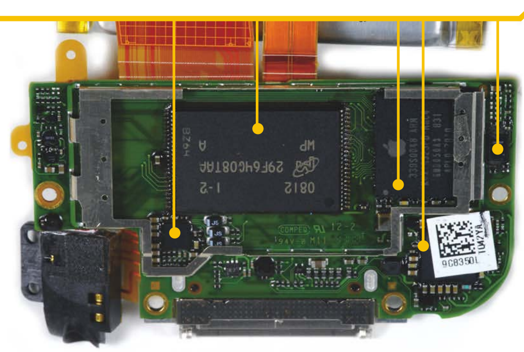


Prying off another RF-shield lid reveals a Broadcom-developed Wi-Fi-plus-Bluetooth-plus-FM combo IC. Although the second-generation iPod Touch features currently include no mention of Bluetooth or FM-radio capability, the Broadcom BCM4325 probably implements the proprietary 2.4-GHz Nike+ peripheral protocol.

The dock connector has encryption support in this product generation. The STMicroelectronics-supplied accelerometer is the largest IC on this piece of PCB (printed-circuit-board) real estate.



A bevy of digital and analog ICs and passive components lies underneath the speaker. They include a 64-Gbit Micron-sourced multilevel-cell NAND-flash memory; an Apple-marked ARM CPU-plus-DRAM, two-die, single-package stack, likely identical to the one in iPhones; an Atmel-supplied 8-Mbit boot-flash-memory chip; the iPod Touch's power-management controller underneath the sticker; and an audio codec rumored to come from Cirrus Logic.



The headphone jack also supports microphone functions in this generation of the product design. The embedded speaker is also new this time around.

POWER SOCs: A “CRAZY” IDEA THAT JUST MIGHT WORK

FOR POWER-MANAGEMENT ICs, FITTING AN ENTIRE POWER SUPPLY, INCLUDING SWITCHING, CONTROL, AND PASSIVE COMPONENTS, ONTO ONE CHIP ENABLES GREATER POWER EFFICIENCY AND LOWER HEAT DISSIPATION. SOPHISTICATED POWER-SUPPLY TOPOLOGIES, MINIATURIZED MAGNETICS, AND FASTER SWITCHING DEVICES MAY COMBINE TO MAKE THE POWER SUPPLY ON A CHIP A REALITY.

BY MARGERY CONNER • TECHNICAL EDITOR

Imagine a cell-phone battery that could supply unlimited power and still fit into its current form factor: the perfect solution to the biggest drawback in today’s portable electronics, right? Wrong. Even with this magic battery, you’d still have the problem of power dissipation: With today’s power-management schemes, a cell phone would quickly become too hot to handle. It’s about efficient power, not available power. In the search for increasingly efficient power schemes, the concept of a power SOC (supply on chip), including power conversion, regulation, management, and passive components, has emerged as the Holy Grail. Some power companies and university researchers are on the quest. Power SOCs would benefit not only handheld electronics, but also laptop computers, which would enjoy extended battery life, and servers, which would have lower energy costs. These power SOCs will appeal to virtually every type of electronic application in the coming years.

Today’s dc/dc PMU (power-management-unit) ICs with external inductors are already much smaller than their predecessors of just a few years ago. For example, Analog Devices’ 6-MHz ADP2121 switcher, which relies on an external inductor, takes up only 5 mm², including the inductor. The proliferation of cores within today’s ASICs is the driving force behind the need for further reducing power-control circuitry into a power SOC. For example, a cell phone might have four or more antennas, including Bluetooth, CDMA (code-division/multiple-access), GSM (global-system-for-mobile)-communication, and 3G (third-generation) units, as well as video and baseband-RF sections. To ensure power efficiency, each core must quickly turn on or off; otherwise, the system would waste power on a core that’s not in use. For fine-grained power control, each core needs its own dc-voltage source, including voltage conversion and regulation. Yet, four or more PMUs hanging off a multicore chip would dwarf the chip, even if they each measure only 5 mm².

You may consider sprinkling a few power-supply modules on the board and using semiconductor switches to turn the cores and subblocks on and off. However, it’s difficult for a power supply to remain efficient over its entire load range—typically, 10 to 90%. A master power supply that spends most of its

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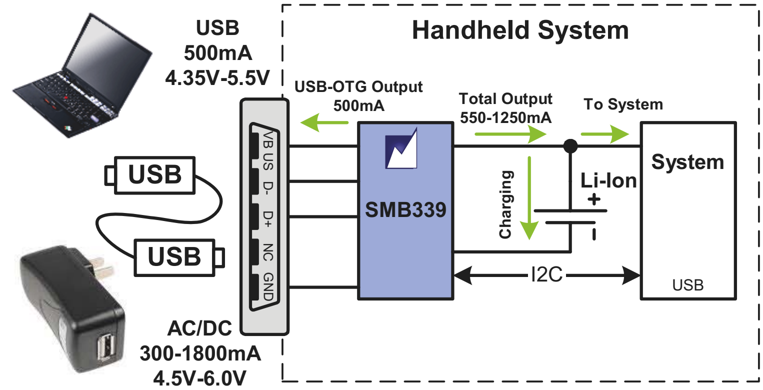

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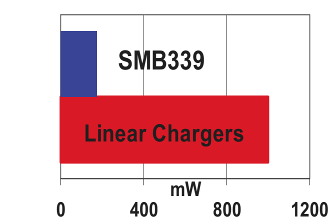
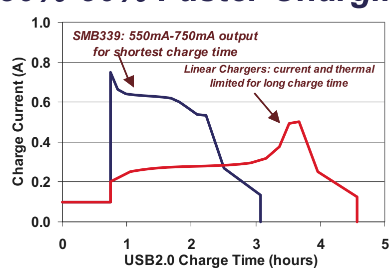
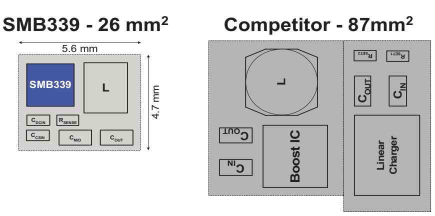


30%-50% Faster Charging



65% Smaller Solution



Battery Charging Solutions for Every Application

	SMB339	SMB137	SMB135/235	SMB239	SMB139
Topology	Switch-mode	Switch-mode	Switch-mode	Linear-mode	Linear-mode
Input Voltage Range (V)*	4.35 to 6.2 (18)	4.35 to 5.5 (16)	4.35 to 6.5 (10)	4.35 to 6.5 (10)	4.35 to 6.5 (10)
# of Inputs/Outputs	1/1	2/2	1/1	1/1	1/1
Maximum Charge Current (mA)	1250	1500	900	525	210
TurboCharge™ Output	Automatic	Automatic	Software/uC	N/A	N/A
CurrentPath™ Control		X			
USB On-The-Go Power	X	X			
Low-Battery Recovery Mode		X			
I2C Interface	X	X	X	X	X
Programmable Float Voltage	X	X	X	X	X
Programmable Charge/Term. Current	X	X	X	X	X
Programmable Input Current Limit	X	X			
Input/Battery OV/UV	X	X	X	X	X
Hardware Safety Timer	X	X	X	X	X
Software Watchdog Timer	X	X			
Battery Thermal Protection	X	X	X	X	X
Automatic Input Current Limit	X				
Automatic Power Source Detection **	X				
IC Thermal Protection	X	X	X	X	X
Package	CSP-20	CSP-30	CSP-15 5x5 QFN-32	CSP-8	CSP-15

* () Indicates overvoltage "holdoff" tolerance
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*Patent pending

AT A GLANCE

- Tiny power supplies on a chip can enable more efficient power management and lower heat dissipation in electronic devices.
- A power supply in a package is already a reality for speeds in the low megahertz.
- Magnetics and switching devices must advance to enable the continued miniaturization of power circuits.

time in a low-current-load range would yield less power efficiency and more system heat.

Power-SOC technology faces two major deficiencies: efficient, cost-effective switching devices and magnetics operating at 20 to 100 MHz or more. True, ultrahigh-speed switching devices exist in the RF realm, but their developers usually base them on exotic semiconductors, rather than inexpensive silicon processes. Designers have also developed magnetics for the RF world, but their purpose has been to radiate power. A power-supply application requires the exact opposite: quiet, nonradiating devices. In addition, magnetic research has been relatively sleepy: As long as high-speed switching devices were impractical, no one needed high-speed magnetics.

To understand the importance of moving to switching frequencies of 20 MHz, 100 MHz, and beyond, take a look at the impact increased switching speeds have had on the size of current PMUs (**Figure 1**). At 500 kHz, the switching magnetics are almost twice the size of the silicon. At today's switching frequencies of approximately 1 MHz, a PMU's passive components are about the size of the power-control- and -regulation circuitry. At 6 MHz, the silicon has almost the same footprint as that of the magnetics. The decrease in capacitor space is even more dramatic. Proponents of power SOCs suggest that, at speeds of 20 to 100 MHz or more, the passive components shrink to the point that you can include them on the control electronics' mixed-signal die.

Cian Ó Mathúna, PhD, a researcher in power magnetics at University College Cork's Tyndall National Institute, predicts that complete power SOCs, including an integrated inductor, will soon be able to fit into a footprint of only 1 mm^2, including the wafer-scale miniaturized inductor on a power-control wafer inside a PSIP (power system in package). From a BOM (bill-of-materials) point of view, there's little difference between a PSIP and a power SOC: If you split a PSIP open, you'll see the silicon switch-

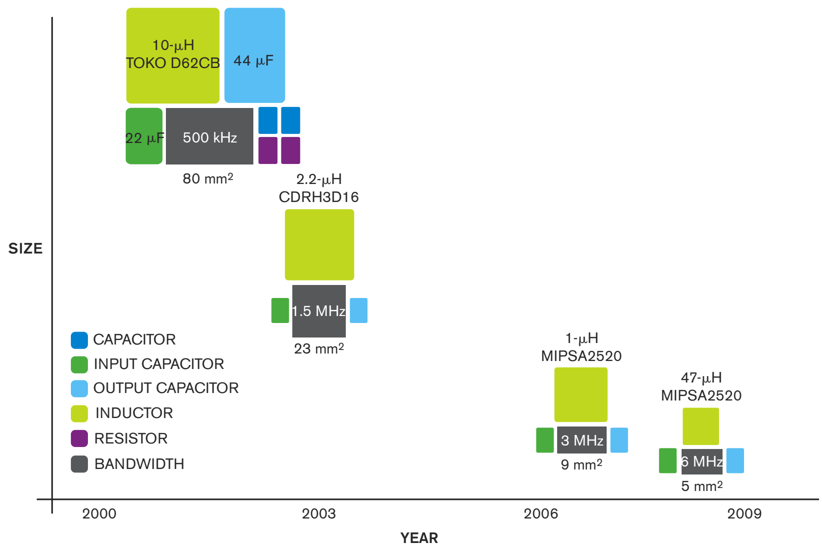

Figure 1 Switched-mode-power-supply ICs, which traditionally have required separate passive components, have decreased in size as their frequency has increased. At 500 kHz, the switching magnetics are almost twice the size of the silicon, and, at 6 MHz, the silicon is almost the same size as the magnetics. The decrease in capacitor space is even more dramatic. However, the ICs' buck-converter topology means that switching losses increase with frequency if the quality of the switching device remains the same (courtesy Analog Devices).

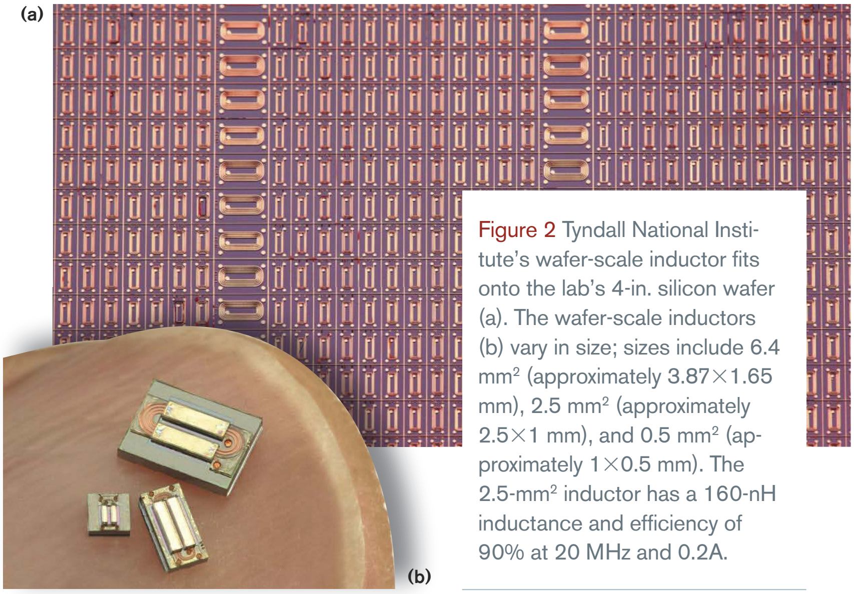

Figure 2 Tyndall National Institute's wafer-scale inductor fits onto the lab's 4-in. silicon wafer (a). The wafer-scale inductors (b) vary in size; sizes include 6.4 mm² (approximately 3.87×1.65 mm), 2.5 mm² (approximately 2.5×1 mm), and 0.5 mm² (approximately 1×0.5 mm). The 2.5-mm² inductor has a 160-nH inductance and efficiency of 90% at 20 MHz and 0.2A.

ing devices and control circuit in one IC and the magnetics and capacitors in one or two other devices—all in one package. Although PSIP devices don't take advantage of the cost reduction and added reliability of wafer-level fabrication, they do meet applications' needs for small parts, simple design, reduced BOM costs, and simpler assembly. Several analog companies, including Vicor, Linear Technology, and Enpirion, have begun to employ this approach.

For example, Enpirion's 1-MHz, 600-mA EP5368Q integrates an inductor, fits into a 3×3×1.1-mm QFN package, and has total dimensions as small as 22 mm², including two external capacitors. The company offers a range of devices that provide as much as 9A and switch at speeds as high as 5 MHz. Enpirion separates the switching and control circuitry from the inductor and places the two die in one package. The company may fabricate the inductor on a silicon wafer or in more traditional multilayer spirals, depending on the application's requirements, according to Michael Laflin, director of product marketing for the company. Those requirements include such factors as load current, inductance, loss budget, and saturation current. The company also takes into account the fact that different magnetic materials exhibit different loss characteristics and behaviors at different frequencies, so magnetic materials also have a part in the inductor-design equation. Enpirion is not forthcoming about the technology behind its inductors because magnetics technology is the "secret sauce" in its devices.

In a paper that Enpirion presented at the PwrSOC (Power-SOC) Workshop last January in Cork, Ireland, the company detailed the lessons it learned in manufacturability, yields, reliability, and cost (**Reference 1**). These prosaic determinants are the keys to developing successful products because, in power management, says Laflin, "cost drives everything."

One of the most experienced research centers for wafer-scale magnetics, the Tyndall National Institute at Ireland's University College Cork uses its 4-in.-wafer line for research in inductors switching at 10 to 100 MHz (**Figure 2a**). These inductors use a "racetrack" geometry of electroplated copper windings encased in a thin-film, electroplated, enclosed, nickel-iron, soft-magnetic core (**Reference 2**). As a reference point, Tyndall researchers demonstrated the inductors operating at 15 to 65 MHz with a monolithic MOSFET and driver-power-train IC. The efficiency for this buck-converter SMPS (switched-mode power supply), including both the converter and the inductor, was 80% at 20 MHz using a commercial chip inductor from Coilcraft (www.coilcraft.com) and with input voltage of 3V, output voltage of 1.5V, and output current of 100 mA. When researchers substituted the Tyndall 2.5-mm² microinductor, the efficiency decreased to 76%. Keep in mind, however, that the Tyndall inductor was not designed for the circuit, as it would

have been in a production design. According to Ó Mathúna, the researchers can tweak both copper and core losses. "We're electroplating copper windings into a mold to a thickness of, say, 35 to 50 microns," he says. "If we go to a higher thickness of copper, we would be able to emulate to a large extent the Coilcraft inductor. In addition, the magnetic-core material has its own inherent losses. In thin-film-plated magnetic materials, that resistivity is going to be very low—that is, those materials are going to be quite conductive. For example, a nickel-iron material has a resistivity of about 45 μΩ-cm. If we move to another magnetic material with closer to 100 to 150 μΩ-cm, we could reduce the eddy-current losses."

The other sticking point in power-SOC development is the high-speed switching device. The buck-converter architecture, currently the most common dc/dc-SMPS topology, has a negative relationship between efficiency and switching frequency: With each increase in switching frequency, efficiency initially falls. "If your design is switching at 5 MHz and you increase it to 20 MHz, you'll have at least four times more switching loss," says Ted Thomas, product-line manager for Texas Instruments' power-management products. "Switching loss ends up dominating the efficiency of the power supply."

However, several topologies have a less stringent relationship between switching frequency and inefficiency. For example, with a ZVS (zero-voltage-switching) topology, the switching device turns on and off only when there is no voltage across it. You use the circuit's resonant frequency to determine the zero-voltage point. Designers have for years used ZVS in ac/dc-power supplies, which must accommodate large currents. The problem with these low-switching-loss topologies is their complexity. If manufacturers could package them in "black-box" power SOCs with the appropriate magnetic components for the design, however, they could become straightforward building blocks for circuit designers.

Technologies employing nontraditional processes are other options now open to designers exploring faster switching devices. For example, silicon carbide can support high switching rates with relatively low losses, but its relatively high cost may rule it out for mainstream, cost-conscious devices. Last September, International Rectifier announced its gallium-nitride platform, a semiconductor process that the company touts as having game-changing higher power density. The company claims that its technological advantage lies in its ability to use inexpensive, readily available silicon wafers to build circuits. This approach lowers cost without sacrificing performance. The devices can also switch at much higher voltages than nonsilicon gallium-nitride products. International Rectifier plans to begin shipping samples of the devices, which operate at less than 6 to 10 MHz, by year's end.

What else is in the future for power SOCs? Look for 10- and 100-MHz PSIPs, both on standard silicon processes, to emerge within the next 18 months and three to five years, respectively. EDN

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ACKNOWLEDGMENTS

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Texas Instruments
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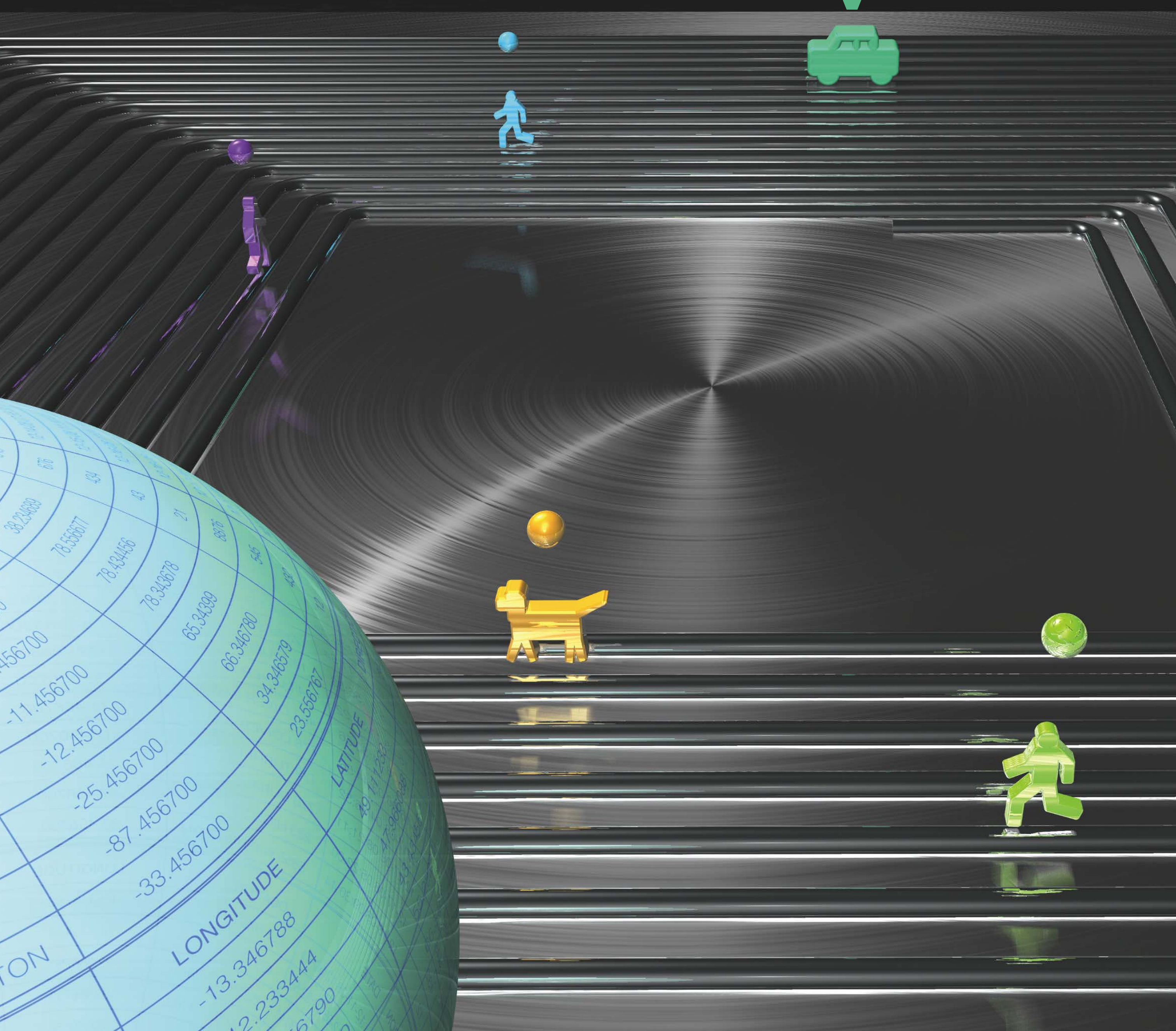
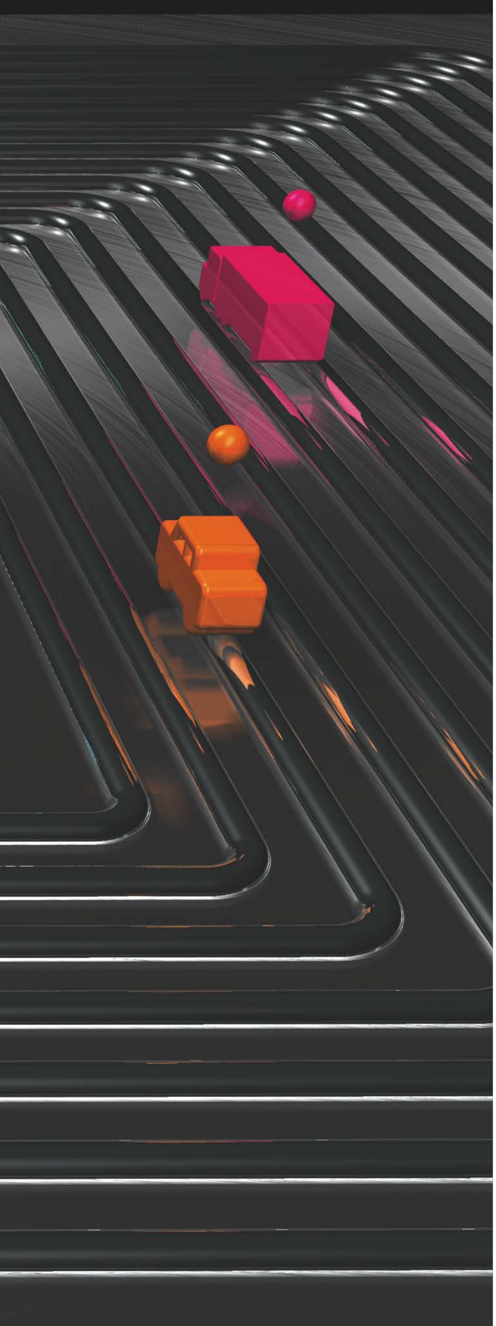
BY WARREN WEBB • TECHNICAL EDITOR

RFID IN EMBEDDED DESIGNS: YOUR MOVE



WITH A BUILT-IN RFID READER, EMBEDDED SYSTEMS CAN EXCHANGE DATA WITH TAGGED ITEMS TO CREATE A NEW CATEGORY OF APPLICATIONS IN TUNE WITH THEIR SURROUNDINGS.



RFID (radio-frequency-identification) technology has the potential to become a common and important element in embedded-system design. In addition to the traditional role of the technology in inventory management, recent advances in RFID tags and high-speed, long-range readers allow embedded-system designers to easily incorporate features such as access control, counterfeit prevention, simplified payments, medical authentication, dynamic pricing, product histories, and remote asset tracking. Embedded-RFID applications typically incorporate a reader within the product or system to add local data-gathering features that enhance the primary functions of the product. You can now find embedded-RFID applications in hotels, prisons, hospitals, retail outlets, farms, casinos, toll roads, and factories, along with a host of commercial and military vehicles. These nontraditional RFID applications will become commonplace as embedded-system developers recognize the value and adopt the technology in new designs.

RFID has verged on being the next big thing since its conception in the middle of the 20th century. The US military used an early form of RFID as far back as World War II to distinguish between enemy and friendly aircraft. The first commercial RFID applications evolved during the 1970s and '80s to track or identify items within a single location. However, developers of many of the early RFID deployments based them on proprietary technology, each using a unique method for communications and requiring specialized reader hardware from the same company as the tag. This lack of standardization resulted in industry fragmentation, slow adoption, and failure to live up to the RFID-technology hype. Today, developers are rectifying most of the early problems, and RFID is a growing industry with dedicated systems in logistics, access control, counterfeit prevention, item-level inventory, contactless payments, and a host of new embedded-system applications.

One of the most basic but widespread uses of RFID technology is the EAS (electronic-article-surveillance) systems that retailers use to wage a high-tech war on shoplifting. The crime costs the industry billions of dollars per year; losses are so high that retailers easily justify the purchase of expensive electronic systems to deter theft. EAS systems employ large antenna panels at store exits and security tags of all sizes attached to high-risk goods. The basic principle behind all EAS systems includes the use of a transmitter to create an electromagnetic field across the store's exit area and a receiver that can detect variations in the field. Small tuned circuits or magnetic material inside security tags that pass through

the exit modifies the field enough for the receiver to detect the change and activate an alarm. Clerks must remove or deactivate security tags when a buyer purchases the item to prevent the alarm from sounding when the customer exits the store.

REFLECTED DATA

Developers of most of the newer RFID architectures based them on low-cost transponders, or tags, which consist of an IC for data storage and communications plus an external antenna. Tags come in two basic varieties: passive and active. Passive tags contain no power source and rely on the RF signal from the reader to induce a small electrical current in the antenna; this current is sufficient to transmit a response. RFID tags transmit data by varying the amount of reflected energy from the reader's RF signal. Passive tags have a range as long as 30 feet, depending on the reader's power output, antenna configurations, and the operating frequency. The RF-LoopTag from Bielomatik, an expandable antenna arrangement, provides both short-range and midrange passive-RFID tags (**Figure 1**).

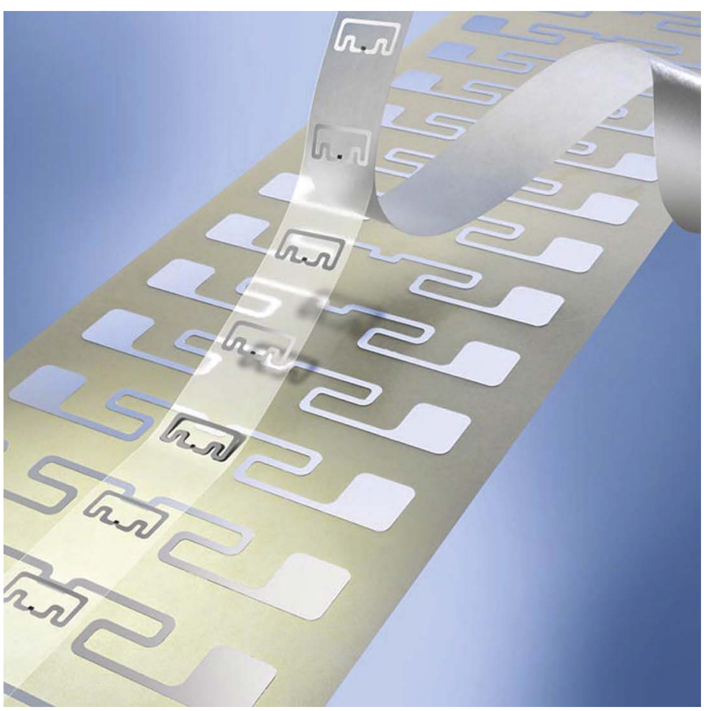


Figure 1 The RF-LoopTag from Bielomatik combines an NXP Semiconductors chip with an expandable antenna arrangement to provide both short- and long-range RFID tags.

You can considerably extend the range with an active-RFID tag that contains its own power source, such as an internal battery. Active tags can transmit data at a higher power level and are generally more accurate than the passive variety. Active tags generally find use with high-ticket items, such as military vehicles or cargo containers. The antenna configurations for RFID systems depend on the application, the environment during read sessions, and the operating frequency.

Governments have allocated several frequency bands for RFID; however, they are not uniform worldwide. LF (low-frequency) devices operate in the 125- to 134-kHz range and find use in applications such as access control, animal identification, asset tracking, and automobile-security key fobs. The HF (high-frequency), 13.56-MHz tags find use in applications with a required reading range of less than 3 feet. Unlike other frequency bands, HF tags are not susceptible to interference when transferring data near metals or water. The UHF (ultrahigh-frequency) band of 860 to 960 MHz is popular for new applications because of the 3 to 5m reading range and the higher data-exchange rates. Typical UHF applications include asset tracking with tags attached to pallets and shipping containers that operators can discover and log as they pass through reader-mounted portals.

Over the past few years, there has been a concentrated effort to create a uniform set of standards for tags and readers in each frequency band. The ISO (International Organization for Standardization) and the IEC (International Electrotechnical Commission) have created a number of RFID standards covering many aspects, such as frequencies, data-encoding methods, and uses of RFID technology. For example, the ISO/IEC 14443 and 15693 standards define the communications-interface protocol for RFID tags used in payment systems and contactless smart cards and in vicinity cards. ISO has also created standards for testing the performance of RFID tags and readers. In addition, the ISO/IEC 18000 series covers the air-interface protocol for automatic identification and item-management systems to track goods in the supply chain.

TRANSPONDERS

Several manufacturers produce RFID-transponder chips for use in tags. For example, Texas Instruments offers a line of Tag-it HF-1-plus-transponder ICs that conform to the ISO/IEC 15693 global standard for product-authentication, access-control, asset-tagging, supply-chain-management, and ticketing applications. These products offer a user-accessible memory as large as 2048 bits in 64 blocks and an extensive command set to select a tag and read, write, or lock stored data. The device identifies multiple transponders appearing in the reader's RF field

AT A GLANCE

- Although RFID (radio-frequency identification) dates back to the 1940s, noninteroperable proprietary products and the lack of standards have hindered the technology's potential.
- Passive-RFID transponders contain no power source and rely on the incoming RF signal to induce a small electrical current in the antenna sufficient to transmit a response.
- Depending on the size of the antenna and the transmitting power, embeddable RFID readers can interrogate transponders moving at highway speeds with ranges exceeding 30m.
- Global standards and business and government mandates have extended the reach of RFID; however, privacy and security concerns continue to hinder universal acceptance.

EMBEDDED SERIAL NOR FLASH MEMORY

Product	Erasable Sector	Speed	Density
M25P†	256 Kb - 2 Mb	50 MHz, 75 MHz	512 Kb - 128 Mb
M25PX	4 KB, 64 KB	75 MHz (Dual I/O)	8 Mb - 64 Mb
M25/M45PE	256 B, 4 KB, 64 KB	50 MHz, 75 MHz	1 Mb - 16 Mb

EMBEDDED PARALLEL NOR FLASH MEMORY

Product	Voltage	Performance	Density
J3 v.D	2.7V - 3.6V	X8, X16 Page	32 Mb - 256 Mb
P30	1.7V - 2.0V, 1.7V - 3.6V	X16 52 MHz Burst	64 Mb - 512 Mb
P33	2.3V - 3.6V	X16 52 MHz Burst	64 Mb - 512 Mb
M29W†	2.7V - 3.6V	X8, X16 Page	4 Mb - 128 Mb
M58BW†	2.7V - 3.6V, 2.5V - 3.3V (55ns)	X32 Burst	16 Mb - 32 Mb

EMBEDDED NAND FLASH MEMORY

Product	Voltage	Page Size	Density
SLC small page	1.8V/3V	512 B	128 Mb – 1 Gb
SLC large page	1.8V/3V	2 KB	1 Gb - 8 Gb
CompactFlash* card	3V/5V	2 KB	64 MB - 4 GB
eMMC*	1.8V/3V	2 KB	1 GB

*Other names and brands may be claimed as the property of others.
†Automotive temp available.

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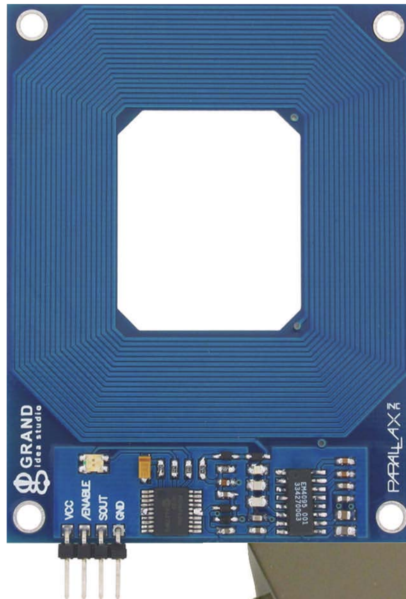

Figure 2 Selling for less than $40, the Parallax reader provides a low-cost, entry-level device to read passive-RFID tags for experimentation or embedded-system applications.

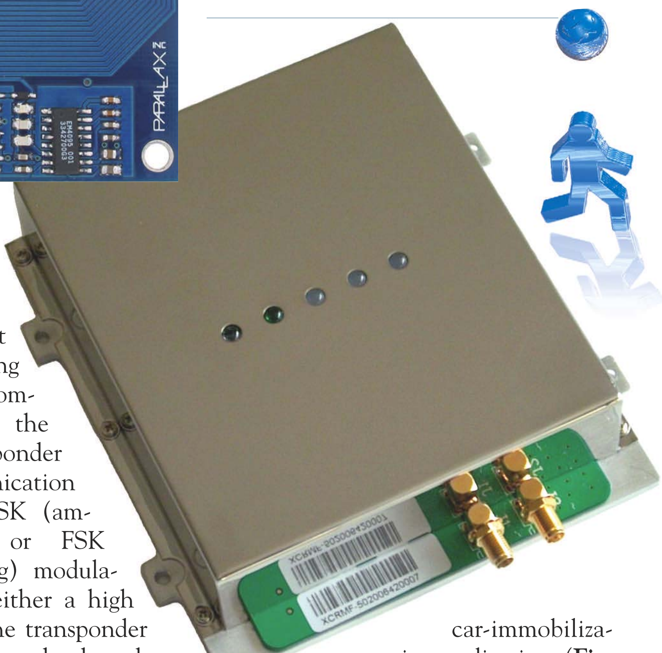

Figure 3 The Model 236002 UHF RFID reader/writer from GAO RFID supports two external antennas and reads moving tags at 10m/sec at a range as long as 7m.

by a unique identifier code that is programmed and locked at the factory. According to ISO/IEC 15693, communication between the reader and the transponder or downlink communication takes place using ASK (amplitude-shift-keying) or FSK (frequency-shift-keying) modulation operating with either a high or a low data rate. The transponder answers in the same mode that the reader used to interrogate it. The technology frame-synchronizes uplink and downlink communications and secures them using a CRC (cyclic-redundancy-check) check sum.

Most embedded-RFID applications require a dedicated reader as part of the design to interpret local tags. A vending machine provides a good illustration of an embedded-RFID application. With a built-in reader, the machine can accept contactless payments from RFID cards. In addition, if the dispensed items are tagged, the machine can keep track of its inventory to automatically order refills. Small and low-cost embeddable readers are essential to these applications and are available from Texas Instruments, SkyeTek, Parallax, and others. For example, a low-cost RFID-reader module that Parallax developed in cooperation with Grand Idea Studio works in passive-transponder tags in access-control, automatic-identification, robotics, navigation, inventory-tracking, payment-system, and car-immobilization applications (**Figure 2**). The module features a 2400-baud serial interface and requires a 5V-dc power source. Prices for the Parallax reader start at less than $40 each.

For more rugged or industrial applications, GAO RFID offers a UHF RFID reader/writer supporting two external antennas (**Figure 3**). Operating in the 902- to 928-MHz frequency band, the Model 236002 targets high-speed warehousing, distribution, and manufacturing applications. The module can identify moving objects at 10m/sec at a range as long as 7m. The module requires 12V dc and communicates over serial RS-232 or Ethernet interfaces.

Embedded-RFID technology is also a perfect fit for high-speed casino-table games in which cheating and sleight-of-hand movements are difficult to detect. With the right data-capture tools, casino operators can monitor players' behavior to detect card counting, adjust promotions, and minimize dealer errors. For example, International Game Technology

and Progressive Gaming International have jointly developed the Table iD table-game-automation system, which combines a software-based table manager and a series of RFID-chip-scanner modules. The latest RFID-gaming chips operate at 13.56 MHz and store more than 10 kbits. During play, chip readers at each position identify and record each player's bets. The Table iD system calculates players' betting patterns, summarizes dealer activity, and records players' decisions once per hour. The system automatically updates information such as average bet and win/loss record without user interaction. Several suppliers manufacture RFID-based gaming tokens suitable for table automation. For example, Gaming Partners International produces the Safechip by Bourgogne et Grasset (**Figure 4**).

RFID technology is starting to replace traditional bar codes in many applications. For example, some libraries have begun to use RFID tags instead of bar codes to identify such information as a book's title, summary, and database information. During the transition, combination systems can read either bar codes or RFID tags during user checkout. RFID systems provide several advantages, such as eliminating the line-of-sight requirement, allowing simultaneous reading of multiple tags, and more data storage, over bar codes. RFID tags can also act as security devices to ensure that all borrowing is properly recorded before books leave the premises. Library cards can use RFID tags to further simplify borrowing by allowing patrons self-checkout of their products.

CHIPLESS RFID

Manufacturers have demonstrated several RFID systems that require no silicon-transponder IC. For example, manufacturers can embed aluminum fibers into printed documents or packaging materials in such a pattern that the fibers reflect an RF signal with identifying data. Another chipless system involves the use of small chemical particles that possess varying degrees of magnetism. The chemical particles become active when you expose them to the electromagnetic waves from a reader and emit a unique signal that the reader interprets as a binary number. With as many as 70 chemicals available, the reader can interpret a unique binary number from an item depending on the mixture of chemicals that the item embeds. Printed-electronics technology can also deposit transponder circuitry and an antenna from specialized ink-jet or high-speed printers directly onto production items or their packaging to create tags that work with both RFID and bar-code readers.

When RFID applications extend to the consumer level, designers must consider privacy issues. For example, strategically located read-

Figure 4 The Safechip from Gaming Partners International works in casino-chip-tracking and security applications and features a 256-bit transponder IC by NXP Semiconductors.

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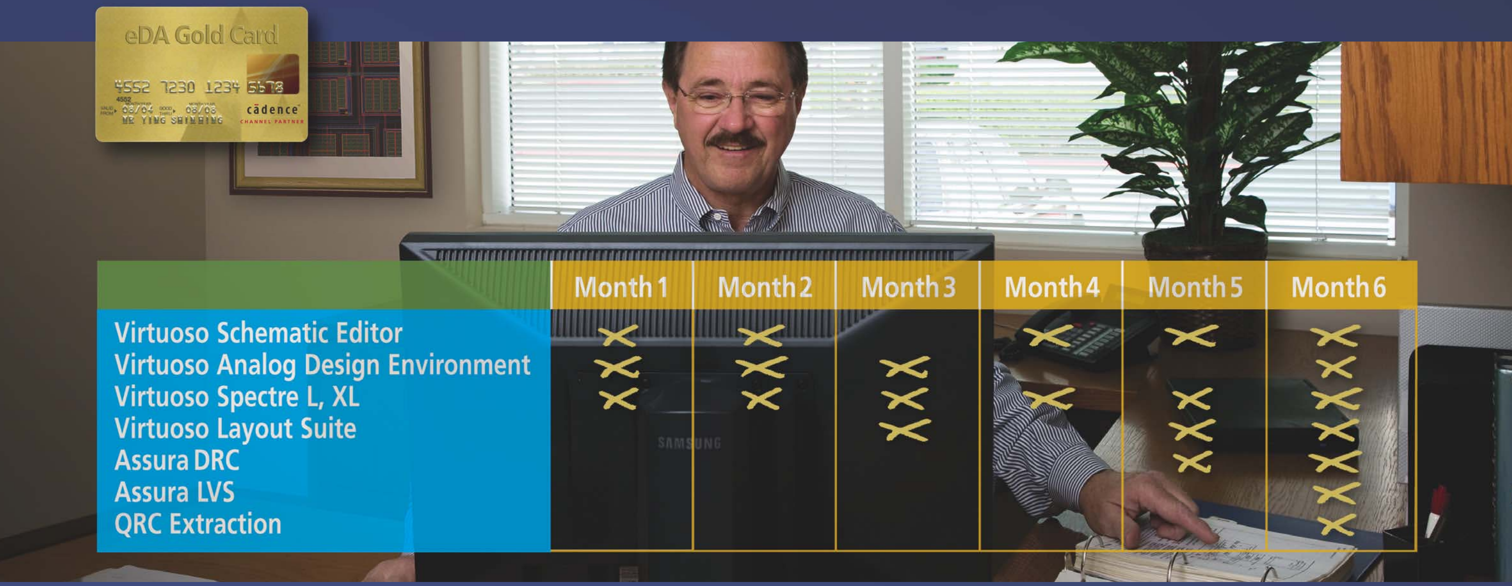

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ers can surreptitiously interrogate many of the smart cards, key fobs, passports, and live transponder tags that use RFID technology. Similarly, as common consumer items such as clothing and accessories become traceable, marketing experts could easily install low-cost readers at store locations to read clothing tags and learn more about the shopping habits of their customers. With item-level serialization, software analysis could determine where and how long ago a customer purchased—or even stole—an item. Retailers could easily devise intrusive marketing campaigns by combining the RFID data with matching customer information that is on file.

Although the use of RFID technology is widespread, it is not yet close to its full potential. Proponents of the technology have frequently predicted that you should be able to walk into a retail or grocery outlet, fill a shopping bag with products, and walk out of the store without going through checkout. RFID readers would simply scan the items in your shopping bag and automatically charge the items to the RFID credit card in your pocket. Now, with new tools and components for embedded-system designers, these types of RFID applications may be closer than you think. Stay tuned.**EDN**

⊞ For a look at some award-winning RFID technology, check out a winner of *EDN*'s 17th annual Innovation Awards, the SkyeModule M9 embedded RFID reader from SkyeTek, at www.edn.com/index.asp?layout=InnovationAwardComp&year=2006&order=40.

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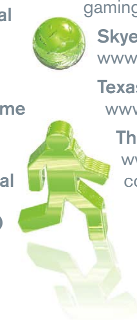

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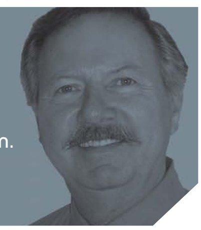

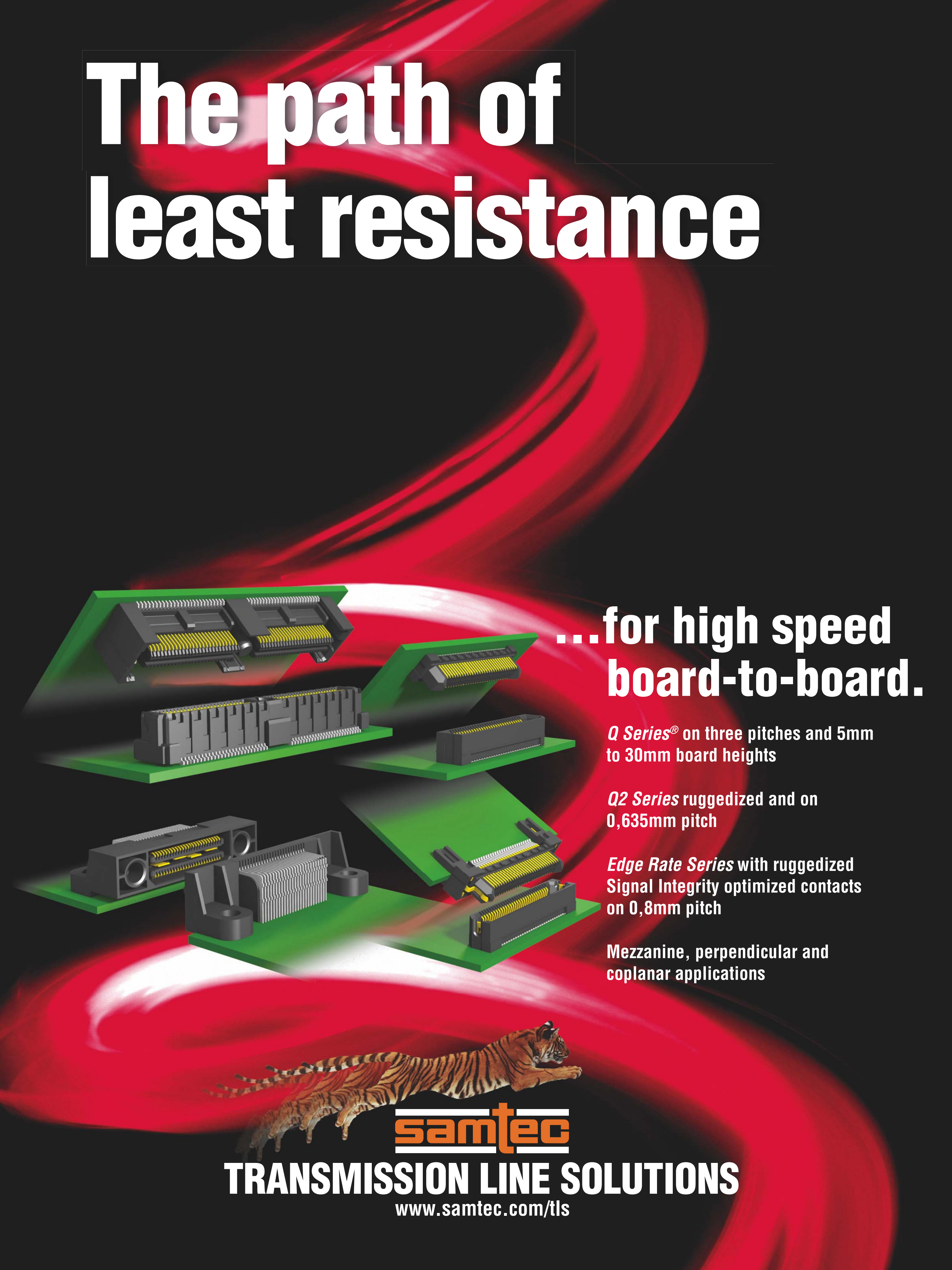
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Driving high-power LEDs in series-parallel arrays

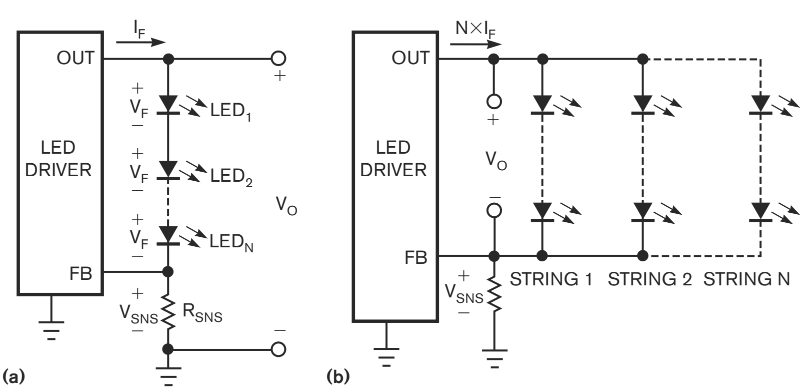
THE LIGHT FROM AN LED IS PROPORTIONAL TO THE CURRENT FLOWING THROUGH IT. THE CHALLENGE FOR THE DRIVE CIRCUITRY FOR APPLICATIONS USING MULTIPLE HIGH-BRIGHTNESS LEDs IS TO GET THE SAME CURRENT FLOWING THROUGH EACH LED AND TO BALANCE THE REQUIREMENTS OF SIZE, POWER EFFICIENCY, LEGAL/SAFETY STANDARDS, AND COST. EVERY BRANCH REQUIRES SOME FORM OF CURRENT REGULATION.

Scarcely a lighting application exists that designers have not considered converting to solid-state lighting, especially as LEDs by leaps and bounds improve both the quantity and the quality of their light output. However, only a few LEDs exist that can emit enough light from a single die to replace a 60W, 900-lm incandescent light bulb. Most applications require multiple LEDs with power ratings of 1 to 5W. When an application crosses the boundary from using just one LED to using two or more, the complexity of the approach increases more than twofold. The more LEDs you add, the more complex the approach becomes. A 900-lm light-bulb retrofit today may need 10 1W LEDs, but a 10,000-lm streetlight of the future may well need 100 LEDs. Binning, or sorting, for luminous flux and dominant wavelength/color temperature ensures that each LED illuminates equally but only as long as an equal current flows through each one.

Placing every LED in a single series chain is ideal from the perspective of equal drive currents (**Figure 1a**). Even a poorly designed LED driver with a wide tolerance of average current or with a wide or varying amount of ripple current still puts the same current through each LED in a series configuration. The LED itself may change in brightness or color temperature, but this situation is preferable to variations in LED light output or color due to current variations.

The trouble comes as the number of LEDs in series grows. You can think of LED drivers as variable-voltage regulators that adjust their voltage output until the desired amount of current flows through their load: the LEDs. The dc voltage required to drive long strings of LEDs can quickly eclipse the limits of widely available electronics components, such as the diodes, transistors, and capacitors necessary for LED drivers. For example, Schottky diodes, which are popular in switching converters, are available only in voltages as high as 100V dc.

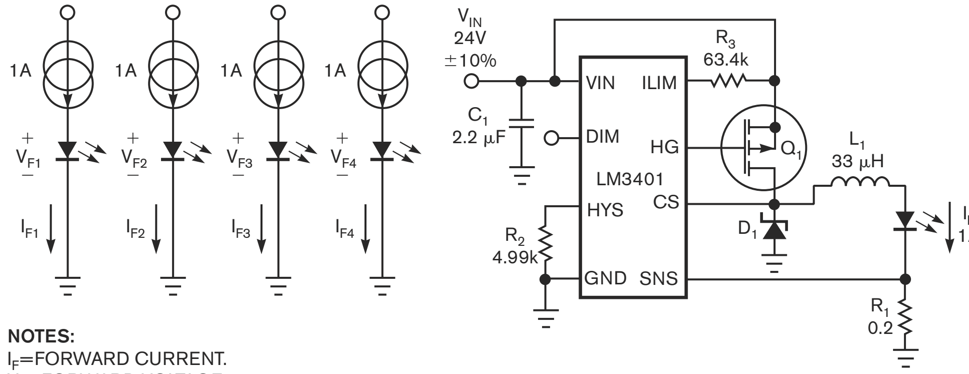
To further complicate matters, each LED has a typical forward voltage, along with a minimum and maximum forward voltage. The more LEDs you place in series, the wider the variation of the dc-drive voltage will be. Finally, the steady drop in forward voltage as LED-die temperature increases further widens the required range of output voltage. In short, the more LEDs an application needs, the more tempting it becomes to try a series-parallel array.



NOTES:
I_F=FORWARD CURRENT.
V_F=FORWARD VOLTAGE.

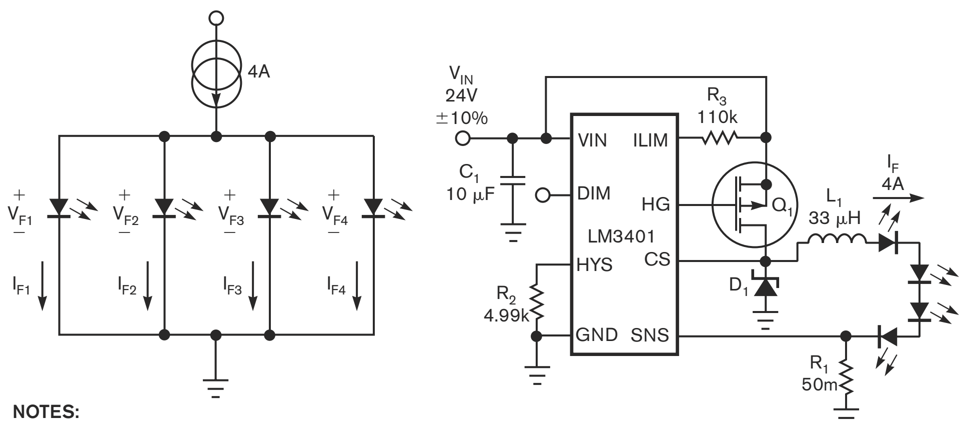
Figure 1 In a series array, the same current flows through all LEDs, equalizing the brightness and color of the string. However, the more LEDs in series, the greater the drive voltage, output voltage, and variation in range (a). One possible LED lighting architecture drives a series-parallel array with N parallel strings using a single driver to reduce the number of driver components (b).

What if you could place the 100 LEDs for the 10,000-lm streetlight in an array of 10 parallel strings of 10 LEDs each? This approach would keep the maximum output voltage 10 times lower than having all 100 LEDs in series. Assuming a typical forward voltage of 3.5V for white LEDs, 350V dc decreases to 35V dc. This reduction is a definite improvement for safety, but at what price? The answer depends on how the LED-drive system balances the currents in each string. Having 10 LED drivers would guarantee independent control over each string, making current balance as good as the tolerances that each LED driver permits. However, adding 10 LED drivers, especially switching-regulator-based drivers with their attendant noise and relative expense, can increase system noise and BOM (bill-of-materials) costs. In an attempt to manage system cost and component count, many lighting-application designers consider driving a series-parallel array with N parallel strings using a single driver that provides higher current (**Figure 1b**).



NOTES:
I_F=FORWARD CURRENT.
V_F=FORWARD VOLTAGE.
SWITCHING FREQUENCY IS 500 kHz.

Figure 2 This test circuit measured the difference in forward voltage between four LEDs with the same part number but from different bins. The test circuit on the left used the same benchtop dc-power supply to power each LED at an ambient temperature of 25°C. The circuit on the right represents a practical 1A LED driver based on a buck regulator. Measuring forward voltage within 5 seconds of applying power minimized the shift in forward voltage due to self-heating.



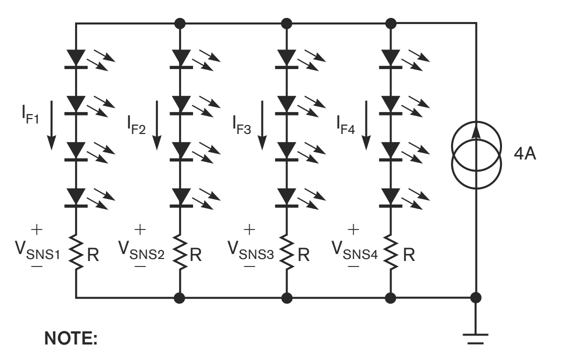
NOTES:
I_F=FORWARD CURRENT.
V_F=FORWARD VOLTAGE.
SWITCHING FREQUENCY IS 250 kHz.

Figure 3 In this test, a 4A current source powered the same four LEDs in parallel.

Higher output current means higher output power, which in turn leads to more expense in an LED driver. The higher the output power, the more likely it is that you must use a switching regulator in place of a linear regulator because of the switcher's higher efficiency. The size of the components, especially inductors and transformers, increases with the current they carry. Even so, one high-power regulator is often more affordable than 10 smaller ones. The problem is that LEDs in parallel are notoriously poor at sharing current. Small mismatches in the dynamic resistance can result in large imbalances in current from string to string. The LED driver can increase the output voltage only until N times the forward current flows. Beyond that figure, such a driver circuit has no way of ensuring equal current in the LED strings.

Figure 2 shows a test of forward-voltage difference between four LEDs of the same part number but from different bins. The same benchtop dc-power supply drove each LED to ensure the same current, at an ambient temperature of 25°C. The testers took measurements within 5 seconds of applying power to minimize the shift in forward voltage due to self-heating of the LED dice. A lighting-application designer could measure the same differing forward-voltage values from these four LEDs if they were in a single series chain. In a second test, the same four paralleled LEDs receive power from a 4A current source (**Figure 3**). Again, testers took measurements at 25°C ambient temperature and within 5 seconds of applying power. Once the LEDs are in parallel, the voltage across each one is equal; however, their varying dynamic resistances draw different currents. LED_2 has the lowest forward voltage at 1A and the lowest dynamic resistance of the group (**Table 1**). This result stands in contrast to LED_1, with the highest forward voltage and highest dynamic resistance. A seemingly small difference of 0.42V translates to more than three times the current flowing through LED_2.

Manufacturers bin LEDs for their luminous flux, color or color temperature, and forward voltage. Most LED manufacturers supply LEDs from only one bin on any given reel. For example, a typical forward-voltage bin might contain LEDs



NOTE:
I_F=FORWARD CURRENT.

Figure 4 To gauge the current matching from string to string in a 4×4 series-parallel array, this test circuit uses 16 LEDs from the same forward-voltage bin, which a 4A benchtop power supply drives. Experimenters repeated the test with randomly selected LEDs from four forward-voltage bins.

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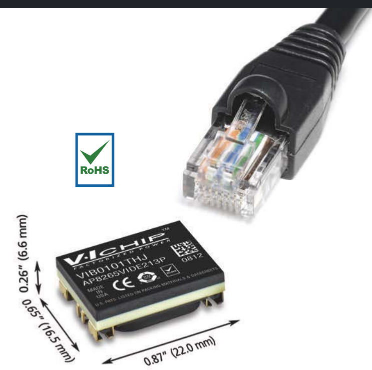

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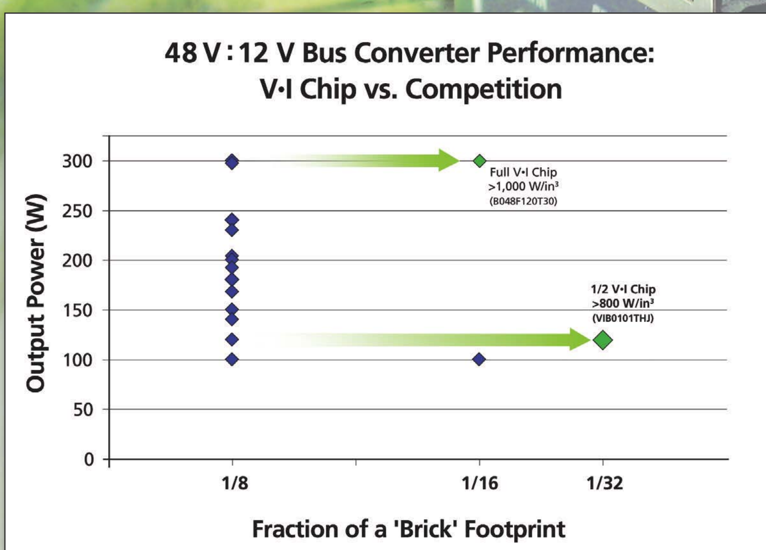

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TABLE 1 TEST RESULTS

Holding forward current constant for an individual 1A current source for each LED

LED no.	Forward current (A)	Forward voltage (V)
1	1	3.83
2	1	3.41
3	1	3.59
4	1	3.52

Holding forward current constant for a single 4A current source powering all four LEDs in parallel

LED no.	Forward current (A)	Forward voltage (V)
1	0.45	3.56
2	1.53	3.56
3	0.91	3.56
4	1.1	3.56

TABLE 2 SERIES-PARALLEL-ARRAY TEST RESULTS

No forward-voltage binning

String no.	Forward current at 25°C (A)	PCB temperature at thermal steady state (°C)	Forward current at thermal steady state (A)
1	1.48	114	1.38
2	0.68	95	0.76
3	1.24	113	1.26
4	0.66	80.8	0.58

Forward-voltage-binned LEDs

String no.	Forward current at 25°C (A)	PCB temperature at thermal steady state (°C)	Forward current at thermal steady state (A)
1	1.08	93.4	0.92
2	1.06	128	1.34
3	1.02	112	0.96
4	0.84	94	0.8

with forward voltages of 3.27 to 3.51V at 25°C when the entire product ranges from 2.8 to 4.2V. The more tightly matched the forward voltages of the LEDs, the better the tolerance in current from string to string when using a series-parallel array. Unfortunately, buying every LED from the same bin is impractical and, in many cases, impossible. LED manufacturers would quickly find themselves drowning in the unpopular-LED bins if they guaranteed a specific bin to each customer. In practice, the manufacturers sell a distribution of devices across many bins, with the possible exception of very large orders.

Even if LEDs did share current equally, putting 100 LEDs in parallel would be just as impractical as having all 100 in series. A second experiment gauges the current matching from string to string in a more practical 4×4 series-parallel array. The experimenters arranged 16 LEDs from the same forward-voltage bin and powered them from a benchtop power supply with 4A.

High-precision-current, 5-mΩ sensing resistors in series with each string allowed individual current measurements and added a minimum amount of resistive ballasting. The experimenters then repeated the test with randomly selected LEDs from four forward-voltage bins. In each case, they took the 25°C measurements within 5 seconds of powering the array. They took thermal steady-state measurements with a handheld IR probe after leaving the array powered for one-half hour. **Figure 4** shows the circuit; **Table 2** details the results.

The results of **Table 2** show that matching the forward voltage of the LEDs in a series-parallel array does improve the current balance at 25°C from a worst-case string-to-string delta of 820 mA in the unmatched array to 240 mA in the matched array. However, even LEDs with forward voltages matched as tightly as the manufacturer can offer allow almost 25% of the 1A target dc current between strings. What's more, as soon as self-heating begins, the current sharing in the matched array becomes almost as poor as that in the unmatched array.

To combat potential mismatch in brightness or color lighting, designers can mix LEDs from different strings and employ blending optics; however, this approach does not address the positive-feedback loop that the drop in forward voltage creates as the LED-die temperature increases. Even when every LED comes from the same forward-voltage bin, one string will inevitably have the lowest forward voltage, and this string will draw more current than the rest. Higher current leads to higher power dissipation, and because this string is hotter than the others, its forward voltage will drop further. To further complicate matters, no binning exists for the rate at which forward voltage drops with die temperature, giving each LED a different slope. You can clearly see this effect by comparing the change in current balance in **Table 2** between 25°C and thermal steady state. In a large array with blending optics, the difference in light output from the hot-test string might not be noticeable, yet the lifetime and lumen maintenance of the hottest LEDs decrease.

Manufacturers could bin LEDs for forward voltage to within 1 mV of one another, which would greatly improve their 25°C current sharing but would greatly increase their cost. Yet, even these extremely tightly binned LEDs, once they heated up, would not share current equally because of their differing forward-voltage/temperature slopes. Even if you take great care to ensure equal heat-sinking for each LED, the current mismatch in series-parallel arrays once they reach thermal steady state makes them impractical. You should include a current regulator in every parallel branch. A ballast resistor may suffice for some applications, and you can use a linear-regulator-current sink/source for others, but a switching regulator is the best choice for greatest power efficiency and flexibility. EDN

AUTHOR'S BIOGRAPHY

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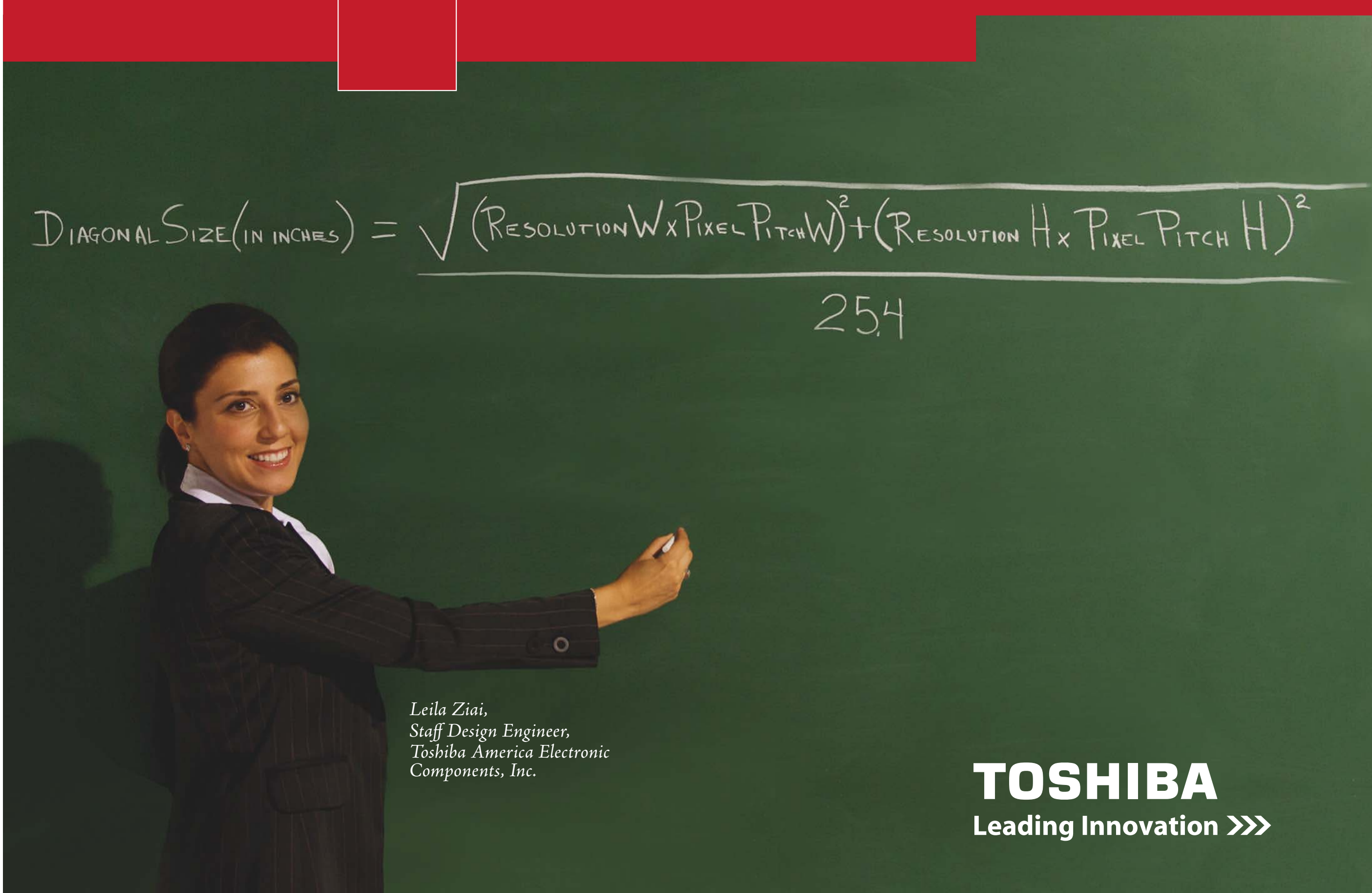

BY JON PEARSON • CYPRESS SEMICONDUCTOR CORP

Get hardware fast

BUILD A TESTBENCH USING THE MICROCONTROLLER IN YOUR PROJECT TO SIMPLIFY THE NEW-TASK LEARNING CURVE, GET A HEAD START ON HARDWARE/FIRMWARE INTEGRATION, AND SHORTEN THE OVERALL DEVELOPMENT CYCLE.

Testing the firmware for your microcontroller project without hardware is about as satisfying as looking at photos of food when you are hungry. But the lack of "real" hardware does not have to delay hardware-based testing of firmware. The same hardware that you use to evaluate a device can potentially serve as a testbench to verify your design. If you already have an evaluation kit, there is no added cost. Additionally, evaluation kits frequently use the same development tools you use to create production designs. With the widespread availability of evaluation boards and modules for low- to high-end devices, almost every engineer can take advantage of this development technique.

Early testbench development can significantly speed the time it takes to integrate the firmware once real hardware is available. But this improvement is not the only reason to take this approach. Having everyone on a project creating testbenches to verify their design will increase the quality of the overall firmware your team creates, and the end result will be more reusable on future projects and by other teams.

EVALUATION MODULES

Most microcontroller vendors provide suitable general-purpose evaluation modules for their products for as little as $69, and you can secure even the more complex—that is, more capable—boards for less than $500. Evaluation boards supply a range of hardware capabilities and demo or production-ready software. To make a good testbench, however, a board needs to provide some functions beyond testing the performance of a microcontroller for an application. Several key characteristics make an evaluation board a good testbench:

- **A generous prototyping area**: Although a breadboard with push-in capability is preferable, solder holes also work. The board should be able to accommodate connection to another microcontroller—the one to which you are applying the tests. Otherwise, you will need two boards.
- **One or more pushbutton or DIP (dual-inline-package) switches**: You can use these switches to manually trigger events, such as selecting a mode, starting a data capture, injecting a one-off signal, or resetting data collection.
- **One or more potentiometers**: These components are worth adding to a board. You can use potentiometers as a simple analog stimulus or to dial in a selection to the testbench or the unit under test. For instance, you might use the pushbutton switch to select the test and the potentiometer to set the amount or duration of the test.
- **Several LEDs**: Use these lights to indicate pass/fail or state information from a test, as well as to signal the beginning or end of a test or state.
- **An LCD or some other form of display**: An LCD can provide more information than LEDs during testing. This ability is especially useful when prompting for action or parameters during a test, as well as for providing instantaneous and finer-grained feedback of key parameters. By employing the display in conjunction with a pushbutton and dial, you can easily devise a capable menu system.
- **A communications interface to a PC**: There is no substitute for simple, straightforward collection of raw data that you can send to a PC for later analysis. Until recently, this collection would occur via RS-232 serial communications with transceiver hardware. Because fewer and fewer PCs have serial

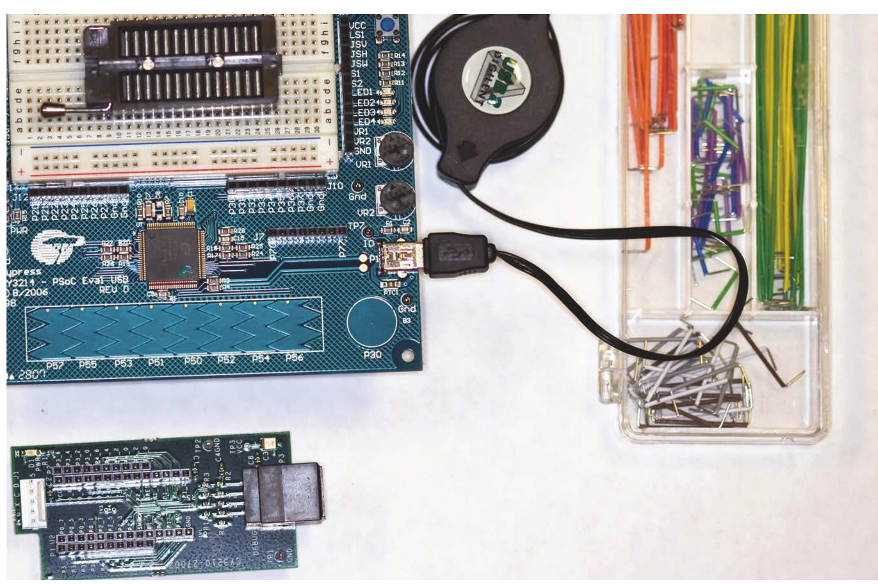

Figure 1 A low-cost evaluation kit, such as this Cypress CY3214-PSoCEvalUSB, can serve as a testbench for a range of devices.

ports, an evaluation board with USB comes in handy as long as the microcontroller vendor has tools to help the USB-novice succeed. A viable alternative is to use a USB-to-RS-232 adapter, which you can purchase for less than $20.

These features meet the minimum requirements to support a workable general-purpose testbench. Most evaluation boards that meet these criteria will undoubtedly include other features that are intended to show off particular features of the microcontroller device. Even if your design does not currently use a feature, you can still include it in the testbench and learn how to use it. In the process, you may discover a useful implementation of the feature for a future design.

Depending upon your application, you may find it convenient to have two evaluation boards. One serves as a testbench that stimulates and monitors the main design in the device under test. This ability is especially important when the devices you are interested in are not readily available in through-hole packages, the prototyping area on the evaluation board is too small to support both the circuitry for the testbench and a device under test, or both situations occur. It is important that the device under test be as similar as possible to the unit you are designing into your end product with the exception of minor differences, such as package type and size. This requirement is not so critical for the testbench, although the more closely the device in the testbench/evaluation kit resembles the device in the end product, the more application-specific insight it can provide to the project at hand.

The only additional tools you should need are soldering equipment, jumper wires, and a PC. Soldering tools are useful for creating a permanent testbench, compared with temporary breadboarding, which you can continue to use once real hardware is available. In many cases, the low cost of an evaluation board makes it more cost-effective than creating a testbench from scratch. Vendors sometimes provide jumper wires for breadboarding with their evaluation boards but not always in sufficient quantity or variety of lengths. Finally, you'll need a PC that can run the development tools and interface to the testbench. If you are using RS-232 on your testbench and your PC does not have a serial port, remember to add a USB-to-RS-232-adapter cable and to confirm its capabilities.

PRACTICE MAKES FASTER

The primary benefit of a testbench is to speed project design by allowing team members to begin integrating their firmware using the board as a reasonable hardware surrogate. Given access to the hardware and system requirements, they can construct a subsystem suitable for independently testing each subsection of a design. Thus, as soon as you design a function, you can implement, test, and verify it in a real-world environment with equivalent operating conditions. If everyone on the team follows this approach, the team members can begin integrating some or all of the functional areas together and run them on testbenches. When the real hardware arrives, final integration will be much smoother.

Using a testbench also provides a buffer against hardware delays. Because hardware is rarely completed on schedule, it delays initial testing. With a testbench, however, software de-

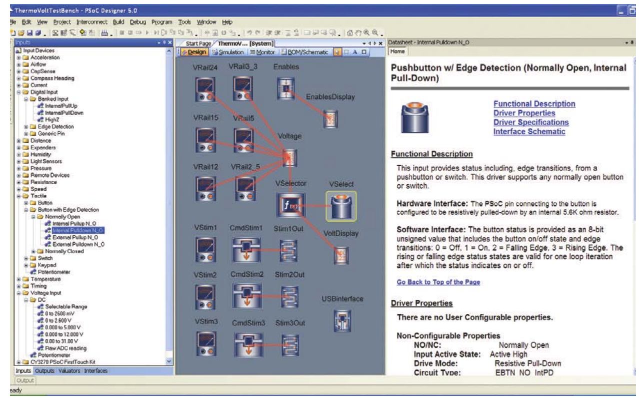

Figure 2 A typical PSoC Designer 5.0 screenshot shows the testbench in the middle; high-level functions on the left; and driver details, such as this pushbutton, on the right.

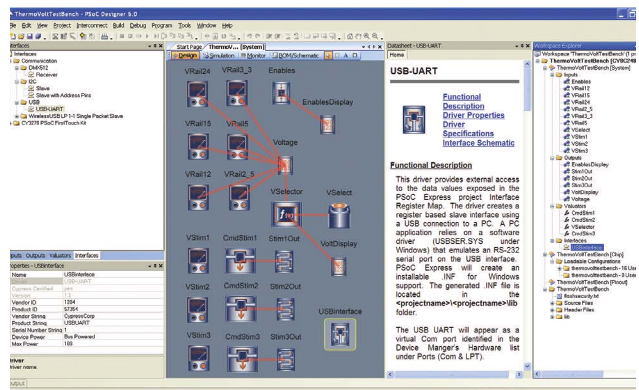

Figure 3 The USB-UART properties and data sheet generate a data-communications protocol that works with a standard Microsoft Windows driver.

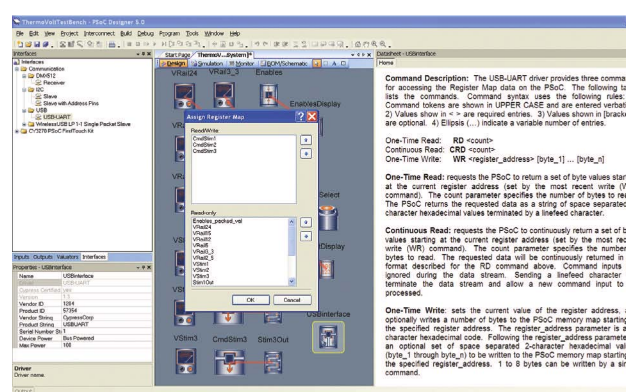

Figure 4 The testbench USB-UART-command protocol has a register map and driver.

velopers can use the delay in hardware availability to ferret out issues and better preserve the design schedule. Additionally, when hardware does arrive and problems arise, early familiarity with the system inspires a level of confidence and capability that allows the team to quickly isolate the cause of the problem. In many cases, the problem will likely be in hardware because software has been rigorously tested at this point. Finally, because real hardware tends to be in short supply when it does arrive, evaluation-board testbenches enable more team members to work concurrently. Such work in parallel results in faster overall development and the ability to meet deadlines.

Another consequence of using testbenches is increased quality of the project at hand, not just because the team is testing the firmware early and often, but also because, in working with the microcontroller to develop testbenches, team members must stretch themselves outside the bounds of their immediate feature or problem. Designing a testbench forces engineers to think about how the function should behave under all circumstances. Engineers must approach design from a preventive perspective with a testbench, rather than take a symptomatic approach to repair problems—as often happens when a system is complete before any real testing occurs. Working early on with this mindset strengthens the individual's skills with the microcontroller. These additional skills become critical to the project's success because, when a problem arises, designers have a greater array of tools at their disposal. More ideas will come from more people from all directions because each had his own testbench to play with.

Finally, if it puts the same rigor on the testbench developments as it puts on the rest of the project—that is, documenting the work and maintaining it in a configuration-management system—the team will have developed a set of testbenches that a formal test group can take advantage of. It can more quickly leverage these basic testbenches into better formal system-level tests. Also, because it can develop and test the functions from one designer with its own testbench, separate from other designers, the team has built a library of well-tested functions that it can combine in many ways to speed a new or different project into production. As before, these regression tests and the hardware to run them are available for immediate use on new projects before any real hardware is available.

TESTDRIVING A TESTBENCH

An example shows how you can use an inexpensive evaluation kit as a testbench. The evaluation kit in this case is a Cypress (www.cypress.com) CY3214-PSoCEvalUSB (**Figure 1**). The evaluation board contains a Cypress PSoC device, CY8C24094, a special version of silicon that can emulate any member of the CY8C24x94 family of devices. Many evaluation boards include similarly flexible devices so that a single evaluation board can serve across a wider range of devices. You can program these devices as you would production silicon or use them with an in-circuit emulator to debug or emulate an application program. This feature is convenient and not uncommon for an evaluation kit. For the example, you could develop a testbench for a voltage-sequencing-and-monitoring application.

Note that, within families of microcontrollers, the differences between devices may be only the amount of memory available and peripheral choice; all other features are identical. Depending upon the portfolio a vendor offers, you'll have the option of selecting a device for your testbench with more features than you may be using in the device under test. For example, you might want to select a testbench microcontroller that supports USB even if your device under test does require USB for data transfer.

In this voltage-sequencing-and-monitoring example, the system has six voltage rails and six enables, one associated with each rail (**Reference 1**). The requirements for the testbench generally depend on what you need the system to do. The testbench in this example uses nine ADC inputs, three DAC outputs, a two-line LCD, seven digital inputs, and a full-speed USB interface. Six of the ADC inputs are for the six voltage rails, and six of the digital inputs are for the six enables. These inputs are the monitors for this voltage-sequencing-and-monitoring project. The three DACs handle voltage-signal injection and act as stimuli for test sequences. The other three

ADC inputs monitor the voltage that the DACs produce. One line of the LCDs displays the state of the enables, and the other line displays one of the six voltage rails, which you select with the pushbutton switch that is tied to the seventh digital input. The USB interface lets you simultaneously access more data from the testbench and log it to a PC.

As assisting in software design continues to become a larger part of selling hardware, manufacturers often design microcontroller-evaluation kits to provide a fast, out-of-the-box experience that demonstrates a device's capabilities. As a result, development tools often include wizards, configuration GUIs, and graphical-design tools that enable engineers to quickly build designs whose development tools would have just a few years ago required days or weeks of manual learning. These tools also speed development of testbench software and interfaces. Additionally, code developed for a testbench often teaches a device's capabilities to engineers and provides some code that they can use in designs.

You can use these same tools, which facilitate fast evaluation, to create in a matter of hours a basic testbench, using high-level system functions that include all of the control and routing firmware necessary to implement the features you desire. You can also use demo or application code to provide core function blocks, such as stitching inputs and outputs together or creating a custom set of data registers that a USB virtual-communications-port driver can access using HyperTerm on a PC.

Figure 2 shows the complete design as a screen capture and divides it into three parts. On the left is the catalog of high-level functions, or drivers. On the right is the data sheet associated with the pushbutton drivers. The middle shows the testbench with six voltage-rail inputs; three stimulus-voltage outputs; three stimulus-voltage inputs; the enable digital input; LCD line 1, which selects a label; and LCD line 2, voltage, which selects an actual reading to display. The USB interface is a drop-in configuration and protocol that works with a Microsoft (www.microsoft.com) Windows-standard driver.

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Figure 3 shows more detail on the USB-UART driver. **Figure 4** shows the register-map ordering and more details of the USB-UART-command protocol.

Again, the benefits to your project of using microcontroller testbenches aren't just those you gain by the testing, but also those you gain by using the microcontroller in a way other than the project requires. Getting started becomes easier, and deeper learning comes from continuing from this starting point to branch out into more specialized testbenches. With quick-start development tools, you can continue to dig deeper and customize the project or simply learn more about the microcontroller and the development tools by looking beneath the surface of the high-level abstraction to all of the automatically generated code available to designers.

Every new project has risks, but a microcontroller-testbench strategy is an effective way to reduce the risk of late hardware and speed hardware and software integration. Hardware cost is low, and the benefits extend far beyond simply providing better testing; they enable formal verification early in the design cycle, which increases the quality of the end product without negatively impacting the design schedule. The team will need to learn all of these capabilities at some point anyway. The more each team member knows about how the microcontroller works, about the development environment, and about each implementation, the better the design—now and in the future. EDN

REFERENCE

1 Buterbaugh, Ernie, "Power Management: Voltage Monitoring and Sequencing with PSoC and I²C," Cypress Semiconductor Application Note AN2379, Dec 13, 2007, www.cypress.com/design/AN2379.

AUTHOR'S BIOGRAPHY

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DESIGN NOTES

Low Profile Synchronous, 2-Phase Boost Converter Produces 200W with 98% Efficiency – Design Note 455

by Victor Khasiev

Introduction

Automotive audio amplifiers require a high power boost converter that is both efficient and compact. High efficiency is essential to keep dissipated heat low and avoid bulky and expensive heat sinks. The LT3782A is a 2- phase synchronous PWM controller, making it possible to produce a low profile, high power boost supply that achieves 98% efficiency.

A 24V Output Boost Converter at 8.5A (Continuous), 10.5A (Peak) from a Car Battery

Figure 1 shows a boost converter that generates 24V from an input voltage range of 8.5V to 18V. Output power is 200W continuous and 250W for short pulse loads, corresponding to 8.5A continuous current and 10.5A pulsed current.

This circuit comprises three major sections. Two are the phase-interleaved power trains, and the third is the control circuit.

Each power train includes an inductor, two switching MOSFETs, a synchronous MOSFET and an output capacitive filter. The output filters are connected together in parallel. Schottky diodes D1 and D2 increase efficiency during the dead time.

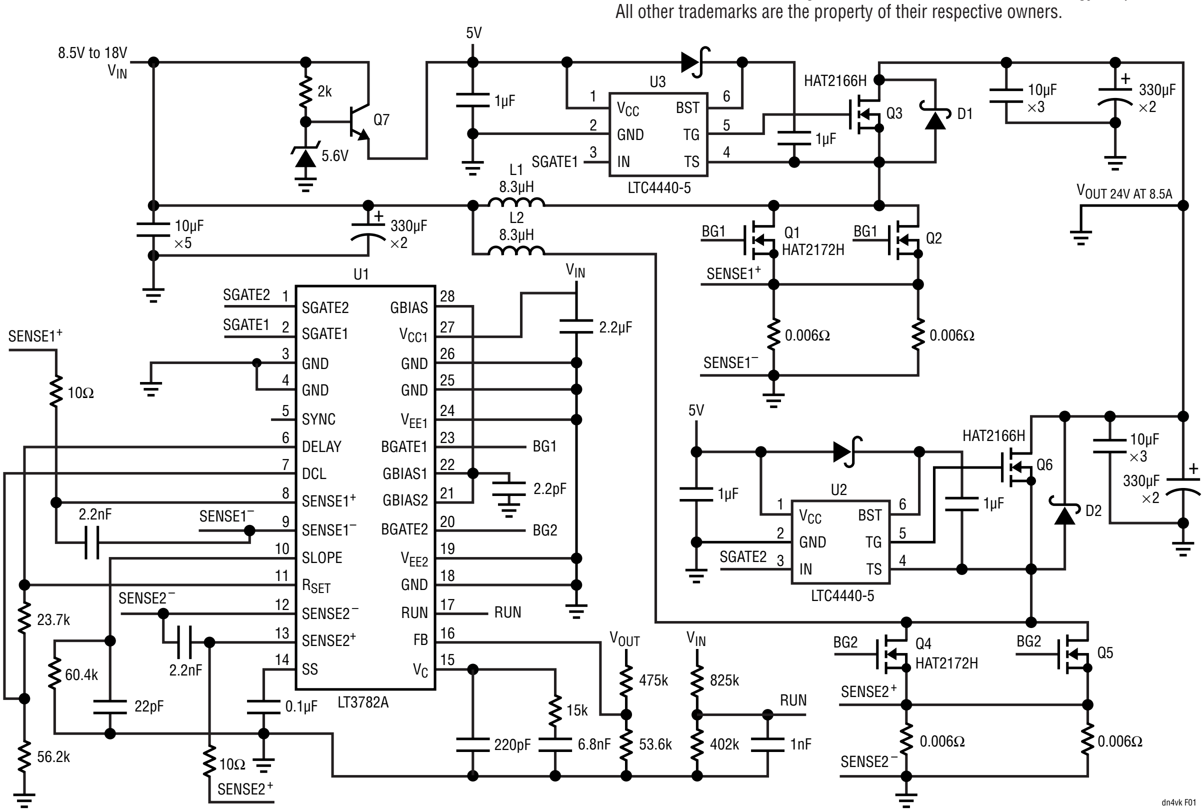

Figure 1. Synchronous Boost Converter Based on the LT3782A (V_{OUT} = 24V at 8.5A, V_{IN} = 8.5V to 18V)

The control circuitry can be further divided into three parts: the PWM functionality based on the LTC3782A (U1) and two high side drivers around the LTC4440-5 (U2 and U3). A linear pre regulator based on Q7 generates the required bias voltage for U2 and U3. This approach allows the use of logic-level MOSFETs to minimize gate losses.

The centerpiece of the control circuit is the LT3782A. This 2-phase PWM controller features low side gate signals and corresponding synchronous signals for high side gate control. Control signals are interleaved by running the two stages 180° out-of-phase. The 2-phase approach with accurate channel-to-channel current sharing minimizes electrical and thermal stress on power train components, and reduces EMI. Using the LTC4440-5 as a high side driver allows for high frequency switching.

Performance Results

This converter aims for high efficiency and low profile, and it succeeds in reaching both goals with efficiency reaching 98% (Figure 2) and a maximum component height of 10.5mm. Output voltage regulation over the full input voltage and output current ranges is better than 2%. Figure 3 shows the transient response with a 3A step load.

Basic Calculations and Component Selection

This section shows how to make a preliminary selection of inductors and MOSFETs. Detailed calculations of the losses and converter efficiency evaluation can be found in Robert W. Erickson's *Fundamentals of Power Electronics*, 2nd edition.

For CCM operation, the maximum duty cycle at low line can be found from the following expression:

$$D_{MAX} = \frac{V_{OUT} - V_{IN(MIN)}}{V_{OUT}}$$

Average inductor current and peak current can be calculated as follows:

$$I_{L(AVG)} = \frac{I_{OUT}}{2 \bullet (1 - D_{MAX}) \bullet \eta}; I_{L(PEAK)} = I_{L(AVG)} + \frac{\Delta I}{2}$$

The peak current through the switching MOSFET is equal to $I_{L(PEAK)}$, and the RMS value of the MOSFET current is:

$$I_{SW(RMS)} = I_{L(AVG)} \bullet \sqrt{D_{MAX}} \bullet \sqrt{1 + \frac{1}{3} \bullet \left(\frac{\Delta I}{I_{L(AVG)}}\right)^2}$$

The peak current through the synchronous MOSFET is equal to $I_{L(PEAK)}$, and the RMS MOSFET current value is:

$$I_{SR(RMS)} = I_{L(AVG)} \bullet \sqrt{1 - D_{MAX}} \bullet \sqrt{1 + \frac{1}{3} \bullet \left(\frac{\Delta I}{I_{L(AVG)}}\right)^2}$$

The MOSFETs should be rated to handle the output voltage plus 20% to 30% of headroom.

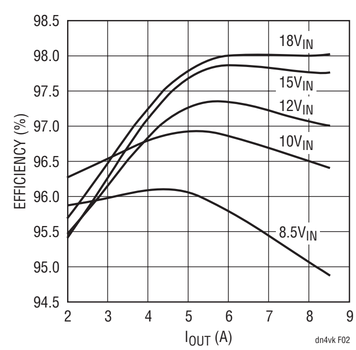

Figure 2. Efficiency vs I_{OUT} (from Circuit in Figure 1)

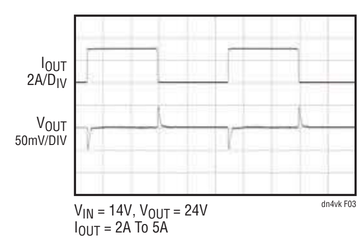

Figure 3. Transient Response of the Circuit in Figure 1 for a 3A Loadstep

Conclusion

The LT3782A based 2-phase synchronous boost converter provides high efficiency, excellent transient response and excellent line and load regulation over a wide input voltage range. High power, high efficiency and a low component profile allow this converter to fit into tight spaces commonly found in automotive environments.

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READERS SOLVE DESIGN PROBLEMS

"Chipiplexing" efficiently drives multiple LEDs using few microcontroller ports

Guillermo Jaquenod, La Plata, Argentina

Actual microcontrollers have powerful bidirectional I/O ports, and you can use different techniques to fully exploit such capabilities. Recent Design Ideas described the "Charlieplexing" method as an effective way to drive $M=N\times(N-1)$ LEDs using only N bidirectional I/O ports and N resistors (**references 1** and **2**). Unfortunately, using Charlieplexing allows you to drive only one LED at a time, so, when using a large number of LEDs, only a tiny slice of time is available to multiplex each LED: $T_{DRIVE}=T/M$, where T is the PWM excitation period. As a consequence, to obtain a given average current and bright LEDs, you must excite them with a current M times higher, and you can't usually obtain such peak currents from the microcontroller port.

This Design Idea describes "Chipiplexing," a method in which you need to add only N cheap, bipolar transistors. This circuit uses PNP types, but you can also use NPN devices. (The term *Chipiplexing* comes from my nickname, Chipi.) The benefits pay the additional cost because you can simultaneously drive $N-1$ LEDs, thereby reducing peak currents $N-1$ times.

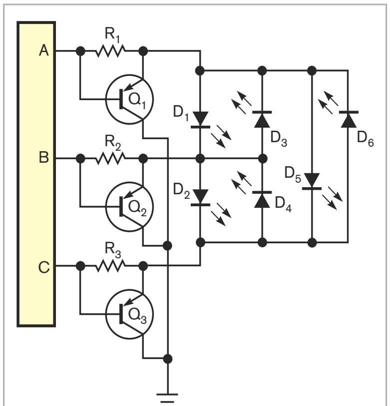

Figure 1 With Chipiplexing, you need to add only N cheap, bipolar transistors to simultaneously drive two LEDs.

Figure 1 shows the approach for $N=3$ and $M=6$, but you can use the same criteria for different values of N; in this case, you can simultaneously drive two LEDs. The current-limiting resistors connect in parallel with the base and emitter of the added PNP transistors, and all the collectors connect to ground. If you set one of the microcontroller ports to zero, or ground, the respective PNP transistor has a grounded base, and its emitter is at a fixed voltage—typically, 0.7V. You can excite every LED whose cathode connects to this emitter through the remaining ports. If you set the port to one, the battery voltage, the LED turns on; if you set the port to high impedance, the LED turns off.

Table 1 shows how there are now nine possible combinations of the

DIs Inside

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TABLE 1 NINE POSSIBLE USEFUL PORT COMBINATIONS TO DRIVE LEDS

A	B	C	D_1	D_2	D_3	D_4	D_5	D_6
V_{BAT}	Ground	High impedance	Yes	No	No	No	No	No
High impedance	V_{BAT}	Ground	No	Yes	No	No	No	No
Ground	V_{BAT}	High impedance	No	No	Yes	No	No	No
High impedance	Ground	V_{BAT}	No	No	No	Yes	No	No
V_{BAT}	High impedance	Ground	No	No	No	No	Yes	No
Ground	High impedance	V_{BAT}	No	No	No	No	No	Yes
Ground	V_{BAT}	V_{BAT}	No	No	Yes	No	No	Yes
V_{BAT}	V_{BAT}	Ground	No	Yes	No	No	Yes	No
V_{BAT}	Ground	V_{BAT}	Yes	No	No	Yes	No	No

three microcontroller ports: the six available when using Charlieplexing to drive one LED at a time and three new combinations to drive two LEDs at a time. The microcontroller port grounds the transistor's base. This action fixes a junction-drop voltage at the emitter and collects and sinks all the LED currents to ground without overconstraining the microcontroller port, which has to sink only the transistor's base current plus 0.7V per resistor. Each of the other ports set to the battery voltage needs to source only one LED current.

With Charlieplexing, two resistors are in the LED-current path; in this case, however, you can easily compute the limiting resistors as $R=(V_{BAT}-V_{LED}-0.7)/I_{LED}$, where V_{BAT} is the battery voltage, V_{LED} is the LED voltage, and I_{LED} is the desired LED current. The benefits are more noticeable as the number of LEDs increases. For N=5, with 20 LEDs, this approach gives 20% of the total time to drive each LED, instead of only 5% of the time using Charlieplexing.EDN

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2. Gadre, Dhananjay V, and Anurag Chugh, "Microcontroller drives logarithmic/linear dot/bar 20-LED display," *EDN*, Jan 18, 2007, pg 83, www.edn.com/article/CA6406730.

Achieve precision temperature control with TEC Seebeck-voltage sampling

W Stephen Woodward, Chapel Hill, NC

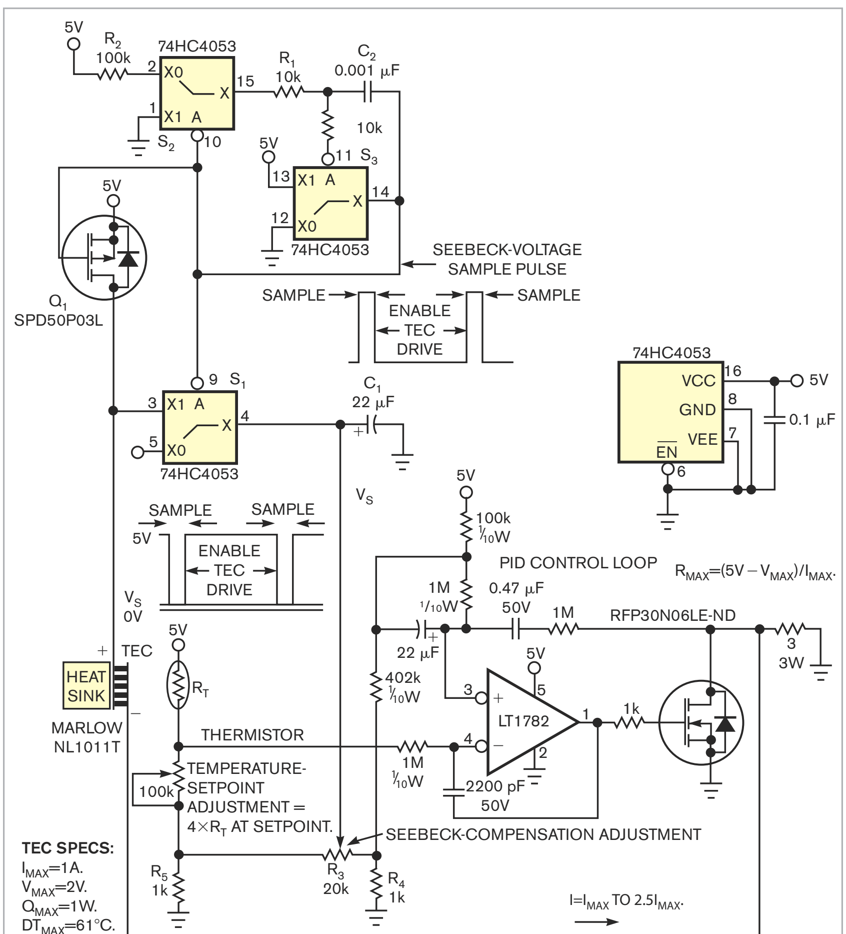


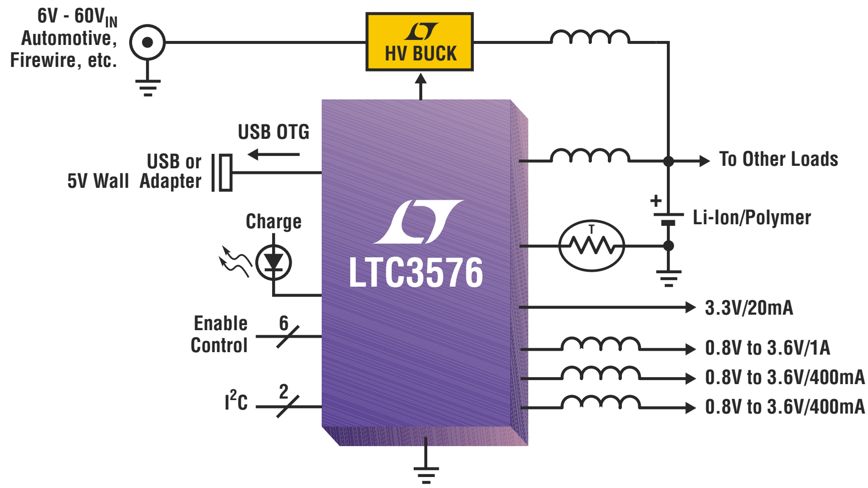
Figure 1 This circuit periodically sets the thermoelectric cooler's drive current to zero, sampling the Seebeck voltage and holding it in a storage capacitor to achieve stable temperature control with real-world heat sinks and thermocouples.

TEC (thermoelectric-cooler) temperature-control systems often have limited stability. The causes of these limitations are the thermal properties of the system, not the performance of the control electronics. Real-world thermal-control systems incur nonzero thermal impedances in the heat-transfer paths between the TEC; the thermal load, which is the object of thermostasis; the temperature sensor—for example, a thermistor; and the ambient temperature.

If the ratios of these impedances don't balance, then even perfect thermostasis of the sensor's temperature doesn't equate to adequate stability of the load's temperature. The circuit in **Figure 1** provides a thermoelectronic design that directly measures the heat flux through the TEC and then uses the measurement to better estimate and cancel the effects of thermal impedances. Its operation is based on the fact that the total voltage that every TEC develops is the sum of two components: an ohmic component proportional to drive current and the Seebeck voltage, V_S, which is proportional to the temperature difference across the TEC and, therefore, to heat flux.

In this circuit, however, the drive current switches to zero approximately every 100 μsec because of the asymmetrical sample-pulse waveform that multivibrator S_2/S_3 generates. Each sample pulse turns off 5V transistor Q_1, which isolates the Seebeck voltage and allows its sampling through S_1 and storage capacitor C_1 to hold it. The duty factor of the sampling pulse, which the

The Right Stuff Inside



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LTC3555/ -1/-3	Switching	I²C	1A, 400mA x 2	-	-	25mA	4 x 5 QFN-24
LTC3556	Switching	I²C	400mA x 2	1A	-	25mA	4 x 5 QFN-28
LTC3567	Switching	I²C	-	1A	-	25mA	4 x 4 QFN-24
LTC3566	Switching	-	-	1A	-	25mA	4 x 4 QFN-24
LTC3577*	Linear	I²C	600mA, 400mA x 2	-	-	150mA x 2	4 x 7 QFN-44
LTC3557/-1	Linear	-	600mA, 400mA x 2	-	-	25mA	4 x 4 QFN-28
LTC3455	Linear	-	600mA, 400mA	-	-	Controller	4 x 4 QFN-24
LTC3558	-	-	400mA	0.4A	-	-	3 x 3 QFN-20
LTC3559/-1	-	-	400mA x 2	-	-	-	3 x 3 QFN-16

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R_1-to-R_2 ratio sets, is less than 10% to avoid significantly reducing the TEC-drive capability of the circuit.

You apply the acquired Seebeck signal to the $R_3/R_4/R_5$ adjustable-bridge circuit, which empirically determines the feedback ratio for both polarity and amplitude to provide best stability. With proper bridge adjustment, you can make gradient cancellation nearly perfect over a wide range of ambient temperatures. The TEC-control circuit in **Figure 1** derives from a previous Design Idea because it eases the incorporation of Seebeck sampling (**Reference 1**). You can, however, adapt Seebeck sampling to virtually any TEC-drive topology. You can further enhance the circuit in **Figure 1** by using nonvolatile, in-circuit-programmable resistors for the $R_3/R_4/R_5$ bridge, automatically optimizing gradient cancellation. One attractive choice is the Rejustor family of monolithic resistors from Microbridge Technologies (www.mbridgetech.com).**EDN**

REFERENCE

1. Woodward, W Stephen, "Thermoelectric-cooler unipolar drive achieves stable temperatures," *EDN*, Dec 3, 2007, pg 98, www.edn.com/article/CA6505571.

Instrumentation-amplifier-based current shunt exhibits 0V drop

Marián Štofka, Slovak University of Technology, Bratislava, Slovakia

Passive current shunts for measuring the value of current flowing through a relatively small-value resistor often have a full-scale voltage drop of 60 mV for higher-power equipment and 200 mV for electronic instruments. Similarly, simple current-to-voltage converters, in which the measured current flows through a sensing resistor, often have even higher voltage drops. In some cases, however, the voltage drop between the input terminal and the ground must be as low as possible; 0V—independent of the value of measured current—is ideal. If your application requires this feature, you can use the current-to-voltage converter in **Figure 1**. In this circuit, resistor R_1 serves as a classic current-sensing resistor, on which the instrumentation amplifier senses the measured current, resulting in the voltage drop. The instrumentation amplifier, along with R_1, not only serves as an inverting current-to-voltage converter, but also creates a voltage through a resistive network at Point B. This voltage is equal in magnitude to a voltage drop on R_1 and has the opposite polarity to ΔV_{R1}. The net result is that the value of voltage at Input A is theoretically 0V, regardless of the magnitude and polarity of the current flowing into the input.

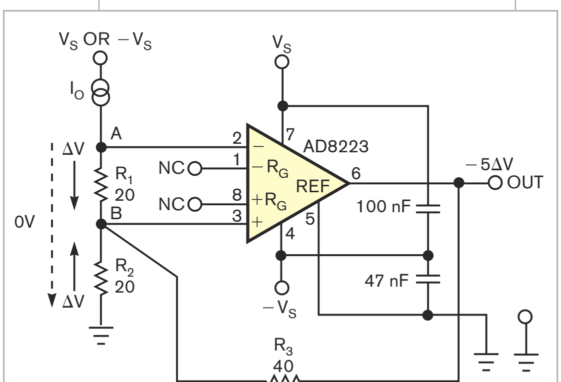

Figure 1 This instrumentation amplifier serves two purposes: It forms a current-to-voltage converter having a transresistance of −5R, and it exerts a voltage drop of opposite polarity at point B, resulting in a zero potential at Input A, regardless of input-current I/0.

The design uses the Analog Devices (www.analog.com) AD8223 instrumentation amplifier because it has a default voltage gain of five; this value remains close to the ideal one with high precision. The typical gain error at the default value of gain is 0.03%, and the worst-case error is 0.1% for the B-grade IC (**Reference 1**). For gain of five and R_1 and R_2 having the same value, you can derive that the value of R_3 is two times that of R_2 for a 0V drop at Input A (**Figure 2**). Resistors R_1, R_2, and R_3 in **Figure 1** should be high-precision, low-temperature-coefficient types. In the experimental circuit with a value of 20Ω for R_1 and R_2, there is an input-referred-current zero shift of 0.8 μA, and the voltage drop at Input A varies by 0.27 mV at a 1-mA input current. Similar slope of negative-voltage variations occurs at Input A for negative-input current. The transfer constant, or transresistance, of the circuit is: $(\Delta V_{OUT})/(\Delta I_{IN})=-5R$.

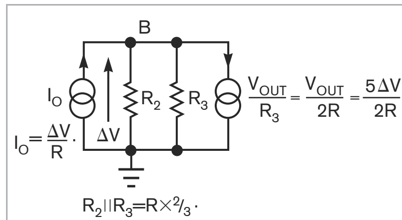

Figure 2 The value of R_3 is two times that of R_2 for a 0V drop at Input A in Figure 1.

Thus, for instance, an input current of 1 mA causes the voltage of −100 mV to appear at the output. Because the output-current capability of the AD8223 is approximately 2.5 times higher for sinking output current than for sourcing current, the input scale can be higher for positive currents by a factor of 2.5. You can further increase the scales for both positive and negative currents by increasing the supply voltages from ±5V to ±12V; you can also use 12V and −5V. If your design requires an even higher input current, place a precision voltage buffer, having appropriately high

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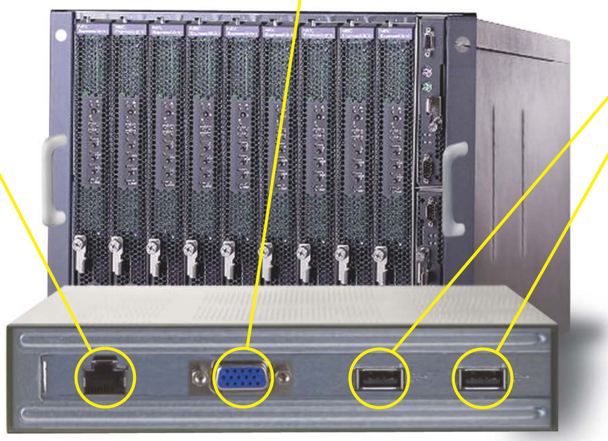

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MAX4887	RGB triple video switch
MAX4929E	2:1/1:2 HDMI control switch
USB	
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MAX4999	Hi-Speed USB 8:1 mux (NEW)
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output-current capability, between the output of the instrumentation amplifier and resistor R_3.EDN

REFERENCE

1 "Single-Supply, Low-Cost Instrumentation Amplifier, AD8223," Analog Devices Inc, 2008, www.analog.com/en/prod/0,2877,AD8223,00.html.

Spark detector uses proximity

Robert Most, Ferris State University, Big Rapids, MI

Hall-effect ICs find use as proximity sensors in applications such as proximity detection and angular-velocity measurement on rotating machinery. Hall-effect devices can detect mechanical motion without mechanical contact. This noninvasive detection is due to the magnetic nature of the Hall effect. A current flowing through a semiconductor in the Y direction produces a negligible potential difference in the X direction (**Figure 1**). In the presence of a magnetic field at a right angle to the current flow, the Z direction, a displacement voltage appears across the semiconductor in the X direction. This effect is the Hall voltage, V_H.

Hall-effect ICs detect, signal-condition, and add hysteresis to the electrical displacement. In essence, the devices measure the electric field, which the magnetic field causes, across the semiconductor in the X direction. Therefore, if you subject the semiconductor to an electric field of sufficient magnitude in the X direction, the Hall-effect device would detect the electric field, as well.

Internal-combustion-engine designs require precise control of spark timing. The microcontroller that controls engine parameters not only changes the spark relation relative to the piston position, but also, in more advanced engines, requires feedback for variable valve timing. In addition, diagnostic aids and engine-troubleshooting hardware can benefit from an easy way to measure spark timing using this novel approach. Even the most basic carburetor adjustments on a lawnmower require a method to measure an engine's revolutions per minute. Four-stroke small engines create a spark on every engine revolution. Therefore, the detection of this spark is a direct indication of engine revolutions per minute.

By simply placing the Hall-effect IC against the spark-plug wire using the correct orientation, you can detect a spark-plug pulse using its electric field. Simply attach the device with electrical tape to the spark-plug wire's insulation. Because the Hall-effect IC incorporates internal signal conditioning and hysteresis, no additional components are necessary to read a basic frequency from the device, unlike with the traditional current-transformer method.

The circuit in **Figure 2** converts the pulses from the Hall-effect IC into a dc voltage that the most basic voltmeter can read. The Hall-effect IC provides an open-collector output. You need only a pullup resistor. The sensor converts the series of generated pulses, which the LM2917 frequency-to-voltage converter from National Semiconductor (www.national.com) converts to a voltage. The selection of C_1 and R_1 scales the output voltage in relation to the range of frequencies that the charge-pump section of this device will encounter. In the case of a four-stroke, single-cylinder engine, a range to 5000 rpm is more than sufficient.

The circuit provides an output voltage as high as 5V and requires a battery-supply voltage of 9V. Operation is straightforward: By pressing the Hall-effect IC against the spark-plug wire, the voltage on the DVM (digital volt-

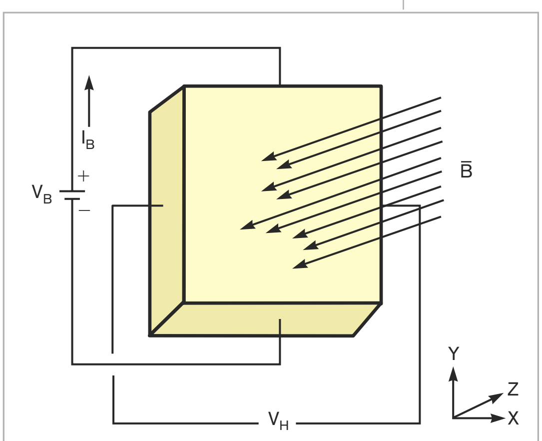

Figure 1 A current flowing through a semiconductor in the Y direction produces a negligible potential difference in the X direction.

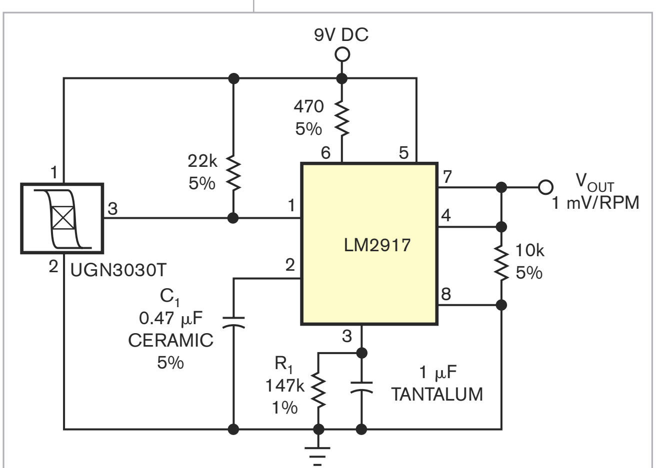

Figure 2 This circuit converts the pulses from the Hall-effect IC into a dc voltage that the most basic voltmeter can read.

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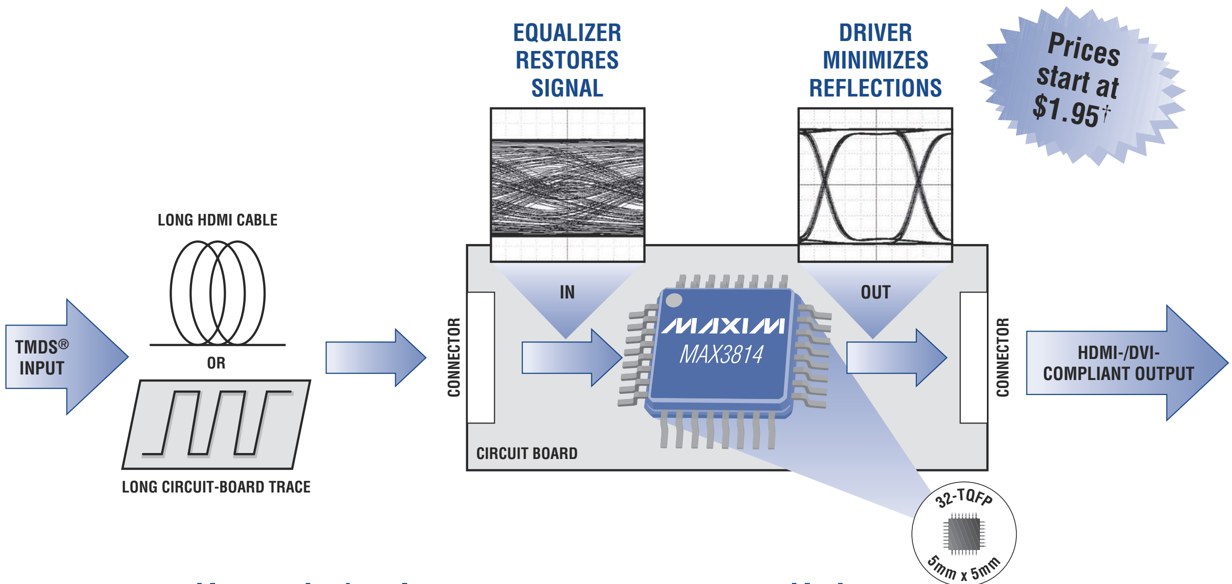
Relief for HDMI/DVI connection woes

Provides 15dB loss compensation and absorbs connector reflections

The MAX3814 equalizer/driver compensates for cable and circuit-board signal losses and absorbs connector reflections—all at a low price. Providing up to 15dB loss compensation for long cables or circuit-board traces, this small, 5mm x 5mm device can be placed right at the HDMI™/DVI™ interface. To absorb connector reflections, a selectable, higher output current enables the use of back-termination resistors. The MAX3814 is ideal for VGA, SVGA, XGA, and UXGA computer resolutions, as well as 480p, 720p, 1080i, and 1080p HDTV resolutions. It is compatible with HDMI 1.3 applications.



HDMI cable extender/equalizer

- Extends 28 AWG HDMI cable up to 36ft
- Extends FR4 circuit board up to 2m
- Adds 15dB (max) loss compensation margin

HDMI cable driver

- HDMI- and DVI-compliant output
- Optional high-current mode for output-reflection termination resistors
- Power-down mode to turn off outputs

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meter) can readily interpret the revolutions per minute. Because the measurement is noninvasive, this method can easily perform repeated measurements or analysis of multicylinder engines. Measurement of automobile engines differs slightly. Automobile engines have mechanical distributors that spark on every other engine revolution. Ignition systems without distributors and with one ignition coil per cylinder also spark on every other engine revolution.

Because there is no electrical contact with the ignition system, this circuit intrinsically provides isolation from the high voltage. Interfacing to microprocessors and microcontrollers thus becomes a matter of compatible logic levels. The Hall-effect IC's power-supply voltage is 4.5 to 24V dc, which enables it to work with standard 5V processors as well as automotive voltages. You can interface multiple sensors to provide ignition diagnosis and timing analysis in automotive applications.EDN

Configure a low-cost, 9V battery-voltage monitor

Paul C Florian, McKinney, TX

This Design Idea describes a 9V battery-voltage monitor whose total parts cost less than 34 cents (**Figure 1**). You configure transistor Q_1 as a 10-mA current sink. LED_1, a Kingbright (www.kingbrightusa.com) WP7104IT, is on when the battery voltage is good. When the battery voltage nears the threshold voltage, the LED gradually dims. It goes out once it reaches the threshold voltage. The threshold voltage for this design is 7.2V, which the values of D_3, LED_1, and R_1 determine. If your application requires a different threshold voltage, you can change these three components' values. You can reduce the PCB (printed-circuit-board) space this circuit requires by using equivalent surface-mount components.EDN

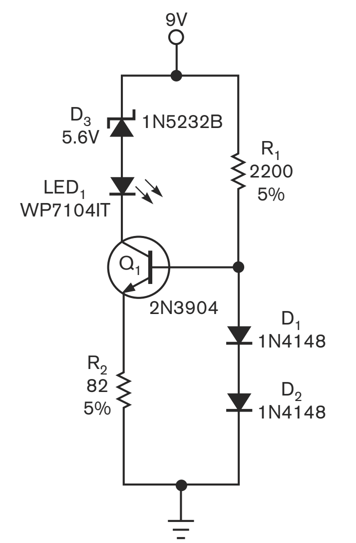

Figure 1 The parts for this 9V battery-voltage monitor cost less than 34 cents.

productroundup

POWER SOURCES

Converters guard against high inrush current and output-voltage overshoot

The AP6714 boost and the AP6015 buck converters have 2.2- and 1.2-MHz maximum switching frequencies, respectively. Claiming 94% efficiency, the synchronous dc/dc converters provide 150-mA quiescent current and extended battery life. Features include a −40 to +85°C industrial-temperature range and an adjustable 1.8 to 5.5V output-voltage range. The converters also guard against high inrush current and output-voltage overshoot using an internal soft-start function, controlling start-up current for 1 μsec. A 1.4A drive current and a 0.9 to 5.5V operating-input-voltage range enable the AP6714 to support all one- to three-cell alkaline, nickel-cadmium, nickel-metal-hydride, and single-cell lithium batteries. An overcurrent-protection feature prevents the converter from overloading when connected to the ground. Driving as much as 800 mA, the AP6015 offers 1.8, 2.5, or 3.3V fixed output voltages or a 0.8V adjustable output voltage to V_{IN}. The AP6015 buck converter and the AP6714 boost converter cost 60 and 70 cents (1000), respectively.

Diodes Inc, www.diodes.com

Stand-alone protection IC integrates cell balancing

Targeting power tools, e-bikes, and portable household appliances, the DS2726 stand-alone protection IC integrates cell balancing for five- to 10-cell lithium-battery packs. Integrating high-side P-channel-FET drivers and cell balancing with fault monitoring into the device provides overvoltage, undervoltage, discharge-current, and short-circuit protection. The IC requires no external microcontroller. Available in a 7×7-mm TQFN-32 package, the DS2726 costs $4.58.

Maxim Integrated Products, www.maxim-ic.com

Converters provide regulated single and dual outputs

Producing 12W/in.^{3}, the AM12T-Z and the AM12TW-Z dc/dc converters come in 2-to-1 voltage ranges at 9 to 18, 18 to 36, and 36 to 75V dc, as well as four-to-one input ranges of 9 to 36 and 18 to 75V dc. The converter provides reg-

POWER SOURCES

ulated and isolated 1600V-dc single and dual self-protected outputs of 2.5, 3.3, 5, 12, 15, ±5, ±12, and ±15V dc. The devices measure 31.75×20.32×10.16 mm and come in DIP-24 packages. Prices start at $21.70.
Aimtec, www.aimtec.com

16th-brick converter provides 3.3V at 25A

The DOSA-compliant SSQE48-T25033 dc/dc converter uses 200-LFM airflow, providing 3.3V dc at 25A with 100% full-rated power at 55°C and 22A at 70°C. Aiming at DPA or IBA power sources for communications, data-server/storage, and workstation applications, the 16th-brick converter features ±3% combined line, load, and temperature regulation and efficiencies as high as 93%. The rugged device withstands 100V input transients for 100 msec. Available in a through-hole-mount pin-out with a 22.9×33-mm footprint, the SSQE48T25033 dc/dc converter costs $32 (1000).
Power-One, www.power-one.com

Single-port midspan adapter suits a range of applications

The high-power, single-port POE-36U-1AT POE (power-over-Ethernet) adapter meets IEEE802.3at standards, enabling 33.6W of power on a single Ethernet port. The device powers systems in a range of applications, including IP telephones, wireless-network-access points, Bluetooth-access points, security cameras, and IP print servers. Measuring 5.51×2.55×1.42 in., the POE36U-1AT adapter costs $44.95.
Phihong, www.phihong.com

Battery-charger IC adapts to individual power sources

Based on a 3-MHz switch-mode architecture, the SMB339 programmable battery-charger IC aims at single-cell lithium-ion- and lithium-polymer-powered systems. The device complies with the USB 2.0 specification, the USB On-The-Go supplement, the USB battery-charging specification 1.0, and the Chinese USB charging specification. The IC automatically adapts to and delivers the fastest battery charge from any power source without the software that typical implementations require. Using the vendor's TurboCharge technology, the IC allows as much as 750-mA charging current from a 500-mA USB source. The SMB339 programmable battery-charger IC costs $1.24 (10,000).
Summit Microelectronics, www.summitmicro.com

MICRO-PROCESSORS

Low-power processor available in single- and dual-core versions

Available in single- and dual-core versions, the low-power version of the MPC8640D dual-core processor integrates two e600 cores, each core with 1 Mbyte of L2 cache, and the 128-bit AltiVec vector-processing engine. Providing pin-for-pin com-

MICROPROCESSORS

patibility with the MPC8641D processor, the device is also compatible with the vendor's QorIQ devices. An available MPC8641D development platform comes with a Linux board-support package. Features include an integrated DDR1/DDR2 memory controller, dual PCIe and RapidIO controllers, quad Ethernet controllers, and a 0 to 105°C temperature range. The single-core MC8640H and the dual-core MPC8640D cost $90 and $120 (10,000), respectively. The MPC8641D reference-design board costs $3075.
Freescale Semiconductor, www.freescale.com

Starter kit suits vendor's ARM7-based microcontroller family

Allowing evaluation of the vendor's ARM7-based CAP customizable microcontroller family, the AT91CAP7X-STK starter kit includes a PCB with the vendor's ARM7-based AT91CAP7S microcontroller and an Altera Cyclone II EP2C8F256C7N FPGA with EPCS4SI8N serial-configuration memory. Additional features include a 2.8-in. TFT-LCD panel, a joystick, 64 Mbytes of application SDRAM, a 10-bit ADC, 256 Mbytes of NAND flash, and a 4-Mbyte data flash. External interfaces include a USB full-speed device, four analog inputs, an external-bus interface, a USART, an SPI, and a debugging UART. The board supports sensing applications with light and temperature sensors and potentiometers. An onboard Cyclone II FPGA contains 8256 four-input look-up-table-logic elements, equivalent to 66,048 CAP7 MP block gates. The AT91CAP7S operates at 80-MHz clock speeds and interfaces to the FPGA using the peripheral I/O. The AT91CAP7S has 32 general-purpose I/O connections and 75 I/Os on the FPGA. The AT91CAP7X-STK starter kit costs $399.
Atmel Corp, www.atmel.com

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All fail down

DANIEL VASCONCELLOS

Computer terminals were failing all over town—not all towns, just those with low humidity, such as Las Vegas, which was particularly hard-hit. I was called in as a consultant for a company there to repair the failing units. The terminals included an 8-bit microcontroller, an LCD, a membrane keypad, and the usual other stuff. Most of the terminals were wall-mounted. Users would unwittingly shuffle across a rug, picking up as much as 30 kV across 300 pF of body capacitance, discharge it through the keypad, and reset the device. This resetting would cloud the unit's memory. The problem was not affecting terminals in the company's offices in high-humidity cities, such as Oahu and Miami.

I looked at the schematic, found nothing suspicious, and asked the engineers what they had tried.

"Everything," they responded. "Nothing worked."

"Everything? Could you give me some details?" I asked.

"The reset line sort of snakes around the board," they answered. "We added a few 0.1-μF capacitors on it. The path of the zap through the keypad didn't get directly to chassis ground; we added many short braid connections. We scoped the power rails and added more bypass capacitors. We added decoupling capacitors to the ac input because, if the chassis gets a pulse, it could couple into the computer board through the ac-input connection. We added some 10-kΩ isolation resistors on the logic driving the keypad. We added more 0.1-μF capacitors here, too, in case the pulse was finding its way back through the drivers. Nothing worked. We tried everything."

I mulled the situation over for a minute. They'd done all the right stuff. The terminal should be working. I could think of no other patch.

"Can I look at the terminal?" I asked.

"Well, here's one," they replied.

"Is this the one with the fixes in it?"

"We took the fixes out," they said. "None of them worked."

It was time to break for lunch anyway; my brain doesn't work well if calorie-deprived. At lunch, after a glass or two of Cabernet, another question occurred to me.

"Listen, just to make sure, when you say you took the fixes out," I said, "you mean you put all the changes in, didn't fix it, and then took them all out, right?"

"No, not exactly. We tried them one at a time. None of them worked," they answered.

I was filled with great happiness and amusement—and, no, not because of the Cabernet I had consumed. "After lunch," I said, "we'll put them all back in—all at the same time."

Sure enough, when we installed all six fixes, the terminal was bulletproof. Pulling them out one at a time, we found the two critical fixes and wrote the ECO (engineering-change order).

The company had fallen into an insidious logic trap: the assumption that the failure has one cause instead of several. One at a time, the fix would help somewhat, but, in most cases, some help is hard to recognize. After installing all the fixes, I could easily see the effect of removing one. Now that I knew how to identify this sneaky trap, I began to see it in many other instances. EDN

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